Louisiana Coastal Area (LCA), Louisiana

Ecosystem Restoration Study

July 2004

Draft

Appendix A – Science and Technology Plan

Page Intentionally Left Blank

LOUISIANA COASTAL AREA (LCA), LOUISIANA

ECOSYSTEM RESTORATION STUDY

APPENDIX A

SCIENCE AND TECHNOLOGY PLAN

TABLE OF CONTENTS

LIST OF FIGURES

Louisiana Coastal Area (LCA), LA
Ecosystem Restoration Study

Science and Technology Plan

1.0 INTRODUCTION

The science of ecosystem restoration is evolving rapidly through theoretical and applied research. The body of scientific knowledge and data for coastal Louisiana has advanced sufficiently to provide a sound basis for implementation of restoration projects incorporating a number of technological and engineering solutions with continuous learning and method improvement. However, certain aspects require increased data and monitoring, modeling, and research and experimentation to decrease uncertainties, especially in the area of predicting ecosystem response to the restoration projects. The Louisiana Coastal Area Ecosystem Restoration Plan (LCA Plan) Science and Technology Plan (S&T Plan) supports the restoration efforts on both fronts. It also supports the opportunity to perform restoration projects in the near-term and thus slow overall coastal degradation while concurrently pushing forward the cutting edge of restoration science, to reduce uncertainty, and rapidly improve the effectiveness of all future restoration activities.

The LCA Program Execution Team requires a formal, clear, concise, and effective process to use all appropriate scientific and technological resources to determine the managerial, non-structural, and structural actions to attain ecosystem restoration goals. The S&T Plan includes the rivers, interior wetlands, open bays, barrier islands, and near-shore environments of Louisiana and contributing watersheds, which are all organized into a hierarchical systems-level approach for restoring and managing Louisiana's deteriorating coast. A fundamental and symbiotic relationship exists between this S&T Plan and the LCA Program Execution Team and other coastal protection activities at the state, local, and Federal level. This S&T Plan reaffirms the need for close and continuing coordination between the scientific community, state and Federal coastal resource managers, and the LCA Program Execution Team.

1.1 Background

Scientists have long recognized the importance of the Louisiana coastal area for fish and wildlife habitat (Coalition to Restore Coastal Louisiana, 1989; Keithly, 1991; Herke, 1993; Michot, 1993), estuarine productivity (Morris, et al., 1990), and ecological sensitivity to human disturbances (Templet and Meyer-Arendt, 1988; McKee and Mendelssohn, 1989; Reed, 1989). This recognition has resulted in considerable efforts to investigate and understand the complex physical (Morris, et al. 1990), chemical (Mendelssohn el al., 1981; Morris, 1991), and ecological (Montague, et al. 1987) processes that drive the system, providing Louisiana with a rich history of scientific studies. Studies on understanding relationships between different habitats and different aquatic species (Minello and Zimmerman, 1991) have been conducted due to the importance of the Louisiana coast's support to numerous estuarine dependent fish and its ability to provide important nursery habitat for diverse fish communities. The coastal areas have also been important for wintering waterfowl with several studies conducted to understand relationships between waterfowl use and habitat conditions. Oil and gas exploration and production have prompted numerous studies on subsurface geologic conditions (Wallace, 1966). Additional geologic conditions have been investigated to aid in understanding deltaic processes that have shaped the Louisiana coast (Fisk, 1944; Kolb and Van Lopik, 1958; Frazier, 1967; May, 1984; Smith et al., 1986; Penland et al., 1988; Dunbar et al., 1994; 1995). Studies on the Atchafalaya River and delta have also contributed to our understanding of deltaic processes (U.S. Army Corps of Engineers, 1951; Fisk, 1952; Shlemon, 1972; Wells and Roberts, 1984; Smith et al., 1986). In addition, numerous studies performed in other ecosystems are applicable to some degree in understanding the ecology and function of the Louisiana coastal area. The results of these investigations provide considerable understanding of the physical, chemical, and biological processes underway within the Louisiana coast. The numerous State-sponsored studies generated from the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) program have developed basic trend information over the last ten years. Studies funded by the National Science Foundation and others have aided in understanding impacts and provided recommendations for improved operations for some existing large water diversion projects.

Although many studies have been conducted in the Louisiana coastal area, most were limited in geographic extent or technical scope. Therefore, while much has been learned from previous efforts, many scientific and technical uncertainties remain. The LCA Plan builds upon a sizable knowledge base, but additional investigations to further reduce the scientific and technical uncertainties and to enhance the likelihood of projects successfully meeting restoration goals would be necessary during later LCA Plan implementation. The LCA Project Delivery Team (PDT) reviewed annual adaptive management reports prepared to assess previously constructed CWPPRA projects. These efforts to identify lessons learned from the many CWPPRA projects, past and future, will also serve as a valuable assessment of what worked and why. Identification of reasons why some projects did not meet project goals would also be very beneficial in reducing potential uncertainties associated with future projects.

Louisiana natural resource managers have also long recognized the magnitude of coastal degradation (Barras, et al., 2003; Barras, et al., 1994; Dunbar, et al., 1992) and have undertaken substantial efforts to address this problem. Advocacy groups have been formed for wetland protection and restoration. Federal and state statutes authorize and finance Louisiana coastal wetland restoration efforts on a large scale (Boesch, et al. 1994). Small-scale restoration projects proliferated throughout the 1990's, as scientists inside and outside of government continued to press for measures to address the land-loss problem regionally, as well as the related issues of offshore eutrophication and hypoxia (Coalition to Restore Coastal Louisiana, 1998).

In spite of these efforts, wetland losses have continued at a significant rate, computed to be 23.9 mi^2 (61.9 $km^{2)}$ during the last 10 years (See Appendix B for more details.) Now more than ever, sound science is needed to support broader, systems-level, integrated coastal restoration to implement the LCA Plan.

A significant component of implementing the LCA Plan is a sound approach to continually incorporate the best science and technology into project design, implementation, and monitoring for restoration and rehabilitation of the ecosystem. The first four sections of this S&T Plan provide a framework for identifying science issues and for improving coordination of scientific activities to support the LCA Program Execution Team along with other federal, state, local, non-governmental and academic efforts. These sections should remain relatively constant as a guiding strategy for the S&T Plan. Section five provides an approach for execution of the S&T Plan, and lists the general types of studies to be conducted and subsequent studies focused on issues of uncertainties. Section 5.0 will be continuously reviewed and updated annually, to assess implemented project outputs and to incorporate lessons learned using the adaptive-management strategy to improve Program Management for subsequent years. Lastly, this S&T Plan will be periodically reviewed and updated to reflect advances in science and technologies.

1.2 Objectives of the Science & Technology Plan

The objectives of the S&T Plan are to provide a strategy, organizational structure, and processes to facilitate integration of science and technology into the decision-making process with Program Management, the Program Execution Team (See Management Section in LCA Main Report for definition.) and the Science and Technology Program (S&T Program) (**figure A-1.1**). Implementation of this S&T Plan would ensure that the best available science and technology are available for use in the design, construction, and operation of LCA Plan projects. This S&T Plan incorporates a process called "adaptive management" – an iterative approach for improving science information and inserting it into management decisions. Therefore, as decisions are implemented based upon best available science, a structure and process must be in place to acquire better information and adjust the implemented actions accordingly to improve the probability of achieving the goals and objectives for implementation of the LCA Plan. Such a process requires the development of key tools – such as development of baseline data and monitoring over time and space, models, data management, and continued research – to provide managers and users with updated information for planning restoration and on the effects of management actions designed to achieve restoration. By participating in and providing information for restoration efforts, scientists can help define and measure the progress of restoration and the success of individual restoration projects and plans.

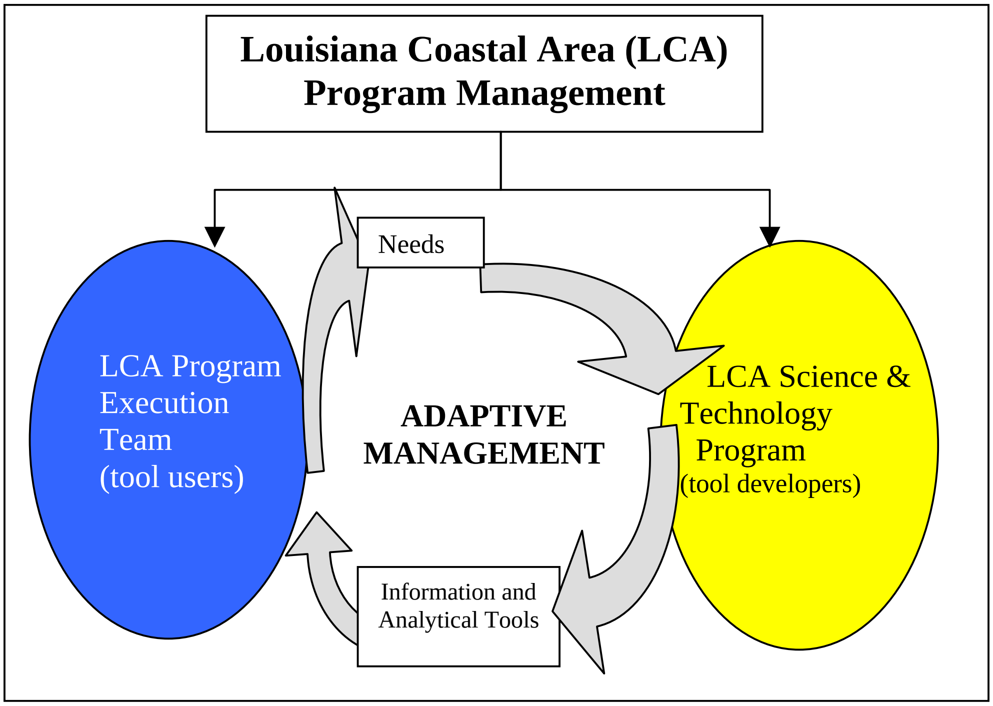

Figure A-1.1. Louisiana Coastal Area (LCA) Program Management. The Program Execution Team will implement the LCA Plan with technical support from the LCA S&T Program. Communication between the Program Execution Team and the S&T Program will be achieved using an adaptive management strategy.

An effective science program should perform the following:

- Work with LCA Program Management and the LCA Program Execution Team to review and assess goals, objectives, and key documents of the LCA Program,
- Identify science needs to assist the LCA Plan in meeting those goals and objectives,
- Establish and maintain independent science and technology advisory and review boards,
- Manage and coordinate science projects for (1) data acquisition and monitoring, (2) data management, (3) modeling, and (4) research to meet identified scientific needs of the LCA Plan,
- Through scientific evaluations, assessments and peer reviews, assure science implemented, conducted or produced by the S&T Program meets an acceptable standard of quality, credibility, and integrity,
- Establish performance measures for restoration projects and monitor and evaluate the performance of program elements,
- Improve scientific understanding of coastal restoration issues within the context of Adaptive Environmental Assessment and Management and infuse this

improved information into planned or future restoration planning, projects and processes conducted by the Program Execution Team,

- Prepare scientific documents including a periodic Science and Technology Report and conduct technical workshops and conferences, and
- Provide reports on science projects to support the Government Performance and Results Act (GPRA).

The intent of this S&T Plan is to provide a foundation, organizational structure and processes for continual dialog among scientists, the Program Management Team, and the Program Execution Team. Priorities for science and technology are established based on the needs of the Program Execution Team (tool users in **figure A-1.1**), as they relate to restoration goals. Priorities are also be based on the needs of Program Management and will be responsive to programmatic, coastwide issues, as well as project-specific issues.

1.3 Role of Science in Ecosystem Rehabilitation and Restoration

The need for a solid scientific foundation to support system-scale ecological restoration has been broadly recognized through similar programs and in statements of agency leaders. Restoration actions are frequently initiated because of societal perceptions rather than in response to a clear, scientifically defined, environmental concern. In the past, restoration managers often relied upon professional opinion to design, implement and manage projects but today's managers realize the value of a continual flow of science information to guide planning, construction and management of restoration projects. The credibility of complex ecosystem restoration programs and the ultimate success of the restoration effort require that science information be made available in a timely fashion and in useful formats to decision makers. An early and fundamental role for science is to provide an understanding of system functions as the basis for determining what processes and attributes need to be restored or managed.

The role for science then is not to make the restoration and management decisions but to:

- Improve coastal restoration decision-making, by identifying science issues to be addressed and develop science information for restoration managers,
- Provide scientific data, analysis, and interpretation that are critical to the planning, design, construction and operation of restoration projects,
- Develop tools, methods, and protocols for system and project -level restoration planning and assessment,
- Minimize uncertainties about the system or system components, which limit restoration planning and execution,
- Assess the immediate and long-term effectiveness of restoration actions in meeting program goals, and
- Provide information and synthesis in a timely manner and useful formats.

There is also growing recognition that restoration efforts simply would not succeed without a sound scientific foundation. These include: (1) placement of the science and technology program in the organizational structure where it can influence decisions, (2) development of relevant science information delivered to managers in a timely manner and useful format, and (3) a commitment to continuous review of monitoring data from restoration projects to adapt their operation and development, as well as the design of future projects, based upon system responses. The LCA Plan approach is based on using the best information in an adaptive management setting, and this S&T Plan demonstrates how these challenges would be overcome as the LCA Plan is implemented.

1.3.1 S&T Program Structure

There are five primary components in this S&T Plan and each component has a different emphasis and requirement. These include: (1) Science Information Needs, (2) Data Acquisition and Monitoring, (3) Data and Information Management, (4) Modeling and Adaptive Management, and (5) Research. Determining science needs requires a continuous process in place that solicits science needs from Program Managers, the Program Execution Team, and scientists. Data Acquisition and Monitoring require standard operating procedures and rigorous adherence to those standards. Data and Information Management requires standards and procedures to assure data can be shared or compiled from a variety of sources. Modeling and Adaptive Management requires broad interactions among scientists, Program Management, and the Program Execution Team. Research requires clear hypothesis testing and a substantial degree of scientific independence but close coordination with the Program Execution Team.

1.3.1.1 Science information needs

The S&T Program, working closely with LCA Program Management and the Program Execution Team, would develop processes to determine science needs. The S&T Program would also assure that both scientists and the Program Execution Team are involved in establishing needs, ranking the importance of each need, and determining feasibility. This is envisioned as a continuous process that is repeated each year for the coast as a whole and more often for solving specific problems. While the emphasis on coastal restoration is an integration of science disciplines, this process must also determine science needs while ranking importance and feasibility on a discipline-by-discipline basis. Broadly this includes disciplines such as:

- Hydrology (flows in rivers, open water and bays, salinity, sediment loads and flows, water quality, nutrients, and storm effects),
- Biology and ecology (mapping habitats and trends, ecological processes and functions and values, species and habitat requirements and restoration, invasive species),
- Geography (base maps, satellite maps, aerial photography, land loss trends, elevation, and bathymetry),

- Geology (barrier island processes, sand sources, faulting, subsidence processes, oceanic processes),
- Oceanography (hypoxia, and oceanic processes),
- Meteorology (weather and storm patterns and intensity),
- Sociology (Cultural change and trends),
- Economics (Effective costs or savings of restoration), and
- Information technologies (Computer systems, geographic information systems, communications, data storage and retrieval, and standards).

1.3.1.2 Data acquisition and monitoring

To be effective in providing data and information to Program Management and the Program Execution Team, this S&T Plan would consider data needs in a geographic hierarchy for the purposes of restoration planning, construction, management and maintenance, and monitoring the relative success of projects. Project success would be measured, not only on a project-by-project basis, but also on its contributions to both basin or sub-basin levels, and entire ecosystems (e.g. Mississippi Deltaic Plain or Chenier Plain). To accomplish this, the S&T Plan would strategically develop, as needed, monitoring systems and collect data within the different ecosystems and integrate this effort with the other ongoing monitoring systems like the CWPPRA Reference Monitoring System for Wetlands as appropriate.

1.3.1.3 Data and information management

The data and information available through numerous agencies and organizations include historic coastal Louisiana datasets, ongoing monitoring collections, and new data collections generated from new restoration projects and science programs. A data and information management system is needed to provide scientists and project managers with decision-support tools to compare historic trends and management strategies with current restoration techniques. This network of geospatial and scientific data would allow project managers to incorporate lessons learned and adjust restoration strategies to best achieve management goals. The data and information framework may be a collaborative effort involving government and private organizations. The end product would be a distributed network of data centers sharing common data structures and standards.

1.3.1.4 Modeling and adaptive environmental assessment and management

Adaptive Environmental Assessment and Management (AEAM) prescribes a management process wherein future actions can be changed by observing the efficacy of past actions on the ecosystem through the use of monitoring and modeling. The efficacy is determined through monitoring and other means to improve the response of the system (Holling and Gunderson, 2002). The adaptive approach recognizes that uncertainty is unavoidable in managing large-scale ecological systems. However, if properly planned and maintained, the feedback element can be used to sequentially improve management actions so that future system conditions become more consistent with program goals and objectives than past actions. AEAM allows development of an iterative and flexible approach to management and decision-making.

1.3.1.5 Research

There are many kinds of science needs that must be pursued through a research and hypothesis or experimental testing process. There is also a danger that research would be conducted for research sake without close adherence to the needs of the program execution. Therefore, it is imperative that the S&T Plan focuses primarily on the needs of the Program Execution Team, but allowing for opportunities within the S&T Plan for creative studies or testing of new technologies that may have utility for future projects. In general, research projects have a variety of possible outcomes and often a substantial amount of uncertainty, and as a result require a great deal of scientific independence. This includes restoration demonstration projects, field or laboratory projects, new technology demonstration projects, characterizations of project areas, or improving our understanding of natural and human caused processes that affect restoration and answer scientific uncertainties. Activities not related directly to the needs of the Program Execution Team would be coordinated and approved by the Program Manager.

1.4 Communication

While scientific understanding of restoration issues has improved, significant gaps remain in the scientific information and adaptive management tools needed for large-scale coastal restoration. Program Management, the Program Execution Team, and the S&T Program (**figure A-1.2**) would coordinate to ensure that the goals and objectives of the LCA Plan are achieved using the best available science. The Program Execution Team and the S&T Program are generally interconnected as follows: the LCA Program Execution Team, representing those needing and using the science information and are the tool users; and the S&T Program, representing those providing the science information and are the tool developers as indicated in **figure A-1.1**. Scientific information would be provided in the adaptive management framework, through monitoring and periodic interpretation, model analysis, and continual improvement in knowledge and methods by supporting research, and interaction between scientists and restoration managers. The framework also provides mechanisms for periodic independent peer review to ensure high standards of scientific investigation. The S&T Plan establishes a framework in which study components are integrated to ensure that sound science directs appropriate restoration choices and long-term environmental sustainability.

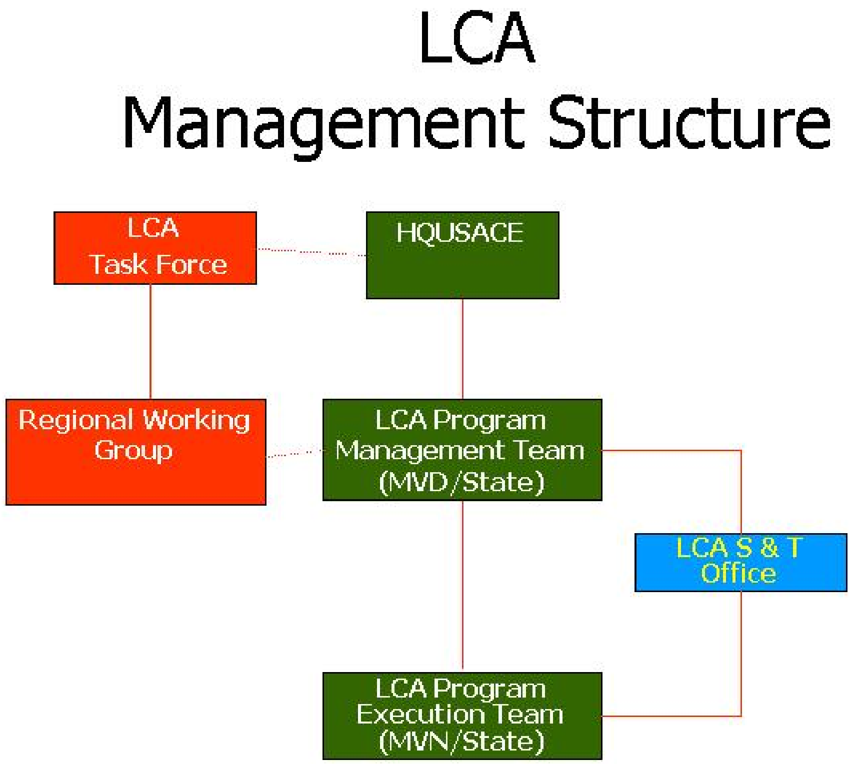

Figure A-1.2. LCA Management Structure. This figure presents the lines of communication between the LCA Program Management Structure and the S&T Office.

This S&T Plan provides a strategy, structure and process to incorporate scientific rigor into the LCA Plan. The S&T Plan also provides a detailed approach for data acquisition and monitoring, data management, modeling, and research activities that support management decision-making. The S&T Program would inventory germane programs and activities, identify data gaps and limitations, and outline actions and resources needed to overcome those gaps and limitations.

The S&T Plan, executed through the LCA Science and Technology Office (**figure A-1.2**), provides mechanisms of coordination that are necessary to ensure timely information transfer to both decision-makers and the Program Execution Team, and to identify resource needs required to provide the scientific information necessary to implement the LCA Plan. The S&T Plan ensures data management and synthesis processes that facilitate information sharing and periodic reporting. An important component of coordination is the timely and accurate identification of data gaps that would be addressed through hypothesis testing. Subsequently, the S&T Plan incorporates independent, technical review committees and advisory boards, and periodic reviews of existing data through coordination meetings and conferences. The S&T Plan would be reviewed annually and updated as part of the adaptive management strategy.

1.5 Science & Technology Program Approach

1.5.1 Science & Technology Plan Development Process

Formalization of a science-based program for the LCA Plan and the institutional framework for management of a mission-directed program of data acquisition/monitoring, research, and modeling, model development, and assessment requires an interdisciplinary and interagency approach. Moreover, successful management of these efforts requires the clear articulation of science and management needs, and ultimately, the agreement of how those needs are organized, prioritized, and accomplished. Therefore, an early step taken to construct the S&T Plan was to conduct a workshop for scientists from Louisiana and across the nation to provide suggestions that could be used by the Corps and State to identify data gaps and enhance development of a science-based Adaptive-Management Decision-Support System. Additionally, a review was conducted of other similarly large ecosystem restoration programs (i.e., Everglades, CALFED, and Chesapeake Bay) to assess lessons learned and to provide direction for development of the S&T Plan proposed herein. The review was an opportunity to examine lessons learned by others and to build upon the strengths of those programs to develop and implement the adaptive- management strategy presented in this S&T Plan. Subsequently, several additional meetings were held with representatives from Federal and state agencies and academia to discuss the goals and objectives of such a S&T Plan and to develop an overall strategy and organizational structure for the S&T Plan. Representatives from the meetings prepared draft sections of this S&T Plan.

1.5.1.1 Strategy

A basic premise of the S&T Plan is that it would be based on *Adaptive Environmental Assessment and Management* (See Section 2 of this Plan for a more detailed discussion.). All work covered by this S&T Plan would be both scientifically defendable and yet relevant to the overall program needs of the LCA Plan. This means that all scientific activities would be conducted in a manner true to scientific principles and methods, but with recognition of the practical and applied destination of the results. This S&T Plan would be implemented in close coordination with LCA Program Management and the Program Execution Team to cover all scientific studies: investigations, data collection, simulations, analysis, modeling, and evaluations sponsored either directly through LCA Plan or conducted in support of the program by coordinating partners. Work conducted through this S&T Plan would comply with generally recognized *Scientific Guiding Principles* and be directed, executed, and reported through a well-defined *S&T Program Structure*.

15.1.2 Science guiding principles

All work would be conducted in compliance with the following Guiding Principles.

1) All scientific work would be ***Responsive*** to and prioritized according to the LCA Plan ***needs.***
2) A strategy of ***Science Leadership and Engagement with the Program Execution Team in Adaptive Management*** would continue to be integrated throughout execution of the LCA Plan and the S&T Office.
3) ***Clear lines of Communication*** would be established and maintained between all members of the scientific team, LCA Program Management, the LCA Program Execution Team, external advisors, and the public as appropriate through a coordinated effort.
4) Scientific activities would promote ***Multiple Discipline Integration*** to optimize synergy and early resolution of potential technological conflicts.
5) The scientific process would be ***Transparent*** with all steps, assumptions, and products available for professional and public scrutiny.
6) All science work would be based upon the ***First Principles***, i.e., incorporate the fundamentals of biology, physics, and chemistry while maintaining temporal and spatial-scale relationships among all variables and comply with the scientific method.
7) Work would be conducted within the context of ***Building Institutional Learning and Scientific Capabilities*** that would provide continuing future technological benefit to the Louisiana coastal area and the study partners.
8) The current ***State of the Technology*** would be applied and transferred into application, but advances in technology would continuously be examined and integrated as appropriate.
9) ***Resources would be Leveraged*** across the various agencies and study partners to promote fiscal responsibility.
10) A ***Peer Review*** process would be established and followed to include research proposal evaluations, in-progress review, and product quality assessments.
11) All members of the S&T Program would be ***Accountable*** for the integrity, quality, ethics and appropriateness of their work.

1.6 Science and Technology Plan Organization

This S&T Plan consists of five sections. Section 1 provides a short background on the problems and challenges of the LCA Plan. It also includes the objectives of the S&T Program, addresses why science is an integral part of the LCA Plan, discusses lines of communication between the S&T Office, Program Management, and the Program Execution Team, and finally provides general guiding principles of the S&T Program. Section 2 discusses the concepts of Adaptive Environmental Assessment Management and strategies for integration of science into the LCA Plan. Section 3 discusses the organizational structure of the S&T Program, its components, and relationship to the LCA Plan. Section 4 identifies some of the scientific uncertainties associated with many of the potential near-term course of actions. Those uncertainties provide the focus of the

S&T Office, particularly during the early years of the S&T Program. This section also provides some examples of potential demonstration projects and the uncertainties to be addressed with those projects. Section 5 of this S&T Plan identifies the assumptions and objectives considered to execute the S&T Plan, a general strategy for Plan development, and more specific tasks to be executed during the first three years of the S&T Program. As one might expect, the level of detail in Year 1 of the Plan is greater than that presented in subsequent years.

Therefore, the first four sections of the S&T Plan collectively provide the foundation for the LCA S&T Program and are not expected to change dramatically from year to year, particularly after the first couple of years. However, Section 5 would be reviewed and refined annually to reflect lessons learned during program planning and execution. It would continuously be reviewed within the S&T Office to build upon our understanding of ecosystem processes and responses and to constantly reduce scientific uncertainties associated with operation of ongoing projects and planning and execution of future projects. This process of learning while doing would be integrated throughout the LCA Plan, and would be integral to effective and responsive execution of the S&T Program.

2.0 ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT (AEAM)

2.1 AEAM Framework

Deltaic coastal ecosystems, like the Louisiana coastal area, are dynamic systems with river and marine processes integrated across global and local scales, each influenced by historical conditions. The Science and Technology Uncertainties, outlined in Section 4.0, as well as incomplete knowledge on the effects of high-energy events such as floods and storms make these large ecosystems inherently difficult to manage. Integration of an AEAM process within the LCA Plan would facilitate management of this complex system to best achieve objectives.

AEAM prescribes a management process wherein future actions can be changed by observing the efficacy of past actions on the ecosystem. The efficacy is determined through monitoring and other means to improve the response of the system (Holling and Gunderson, 2002). The adaptive approach recognizes that uncertainty is unavoidable in managing large-scale ecological systems. If properly planned and maintained, the feedback element can be used to sequentially improve management actions so that future system conditions become more consistent with program goals and objectives than past actions. AEAM allows development of an iterative and flexible approach to management and decision-making.

The structure for an AEAM framework for coastal Louisiana would support a combination of passive and active management approaches to facilitate incorporation into existing restoration and management programs. Programs in Louisiana such as the CWPPRA already support monitoring of project-specific goals and objectives and have previously conducted passive adaptive management reviews. At a project level, the Caernarvon Freshwater Diversion has incorporated scientific manipulations that test the assumptions of its operations. The freshwater diversion project supports an iterative approach and emphasizes that management actions can be viewed as experimental manipulations of the ecosystem. The results of the Caernarvon manipulations were monitored and studied via supporting research, and the acquired data were used to influence future management decisions. In addition, examination of historical trends provided valuable information. The effectiveness of an active AEAM approach, such as used at Caernarvon, is determined by the magnitude of system manipulations required to produce measurable changes in the selected performance measures and the ability to unequivocally attribute measured changes to the management actions.

All organizations within the LCA Management Structure have a role in implementing AEAM. The LCA S&T Office would make AEAM recommendations to Program Management and the Program Execution Team based on assessment of monitoring data and the development of new tools or technologies. Specifically, the

Program Manager is responsible for the overall program and issuing programmatic guidance to make necessary adjustments to better meet program objectives. The Program Execution Team would implement changes directed by the programmatic guidance. **Figure A-2.1** depicts this iterative process and the roles of the different groups. It is important to note that the scope of decisions presented in the "decision process" in **figure A-2.1** would differ in scale. One way of expressing this is to distinguish between strategic decision and tactical decisions. Strategic decisions comprise the decisions about the nature and timing of large projects and major policies related to the overall programmatic effort. Tactical decisions comprise those decisions about implementation and operation that are necessary for the projects and policies to succeed. The AEAM framework applies to both strategic and tactical decisions about coastal restoration.

The LCA Plan has benefited from a review of lessons learned over the past several years in CWPPRA, and AEAM would be more effectively implemented due to those lessons learned. CWPPRA-initiated tool development, such as the Coast-wide Reference Monitoring System (Steyer et al., 2003), would be very useful within the LCA AEAM effort.

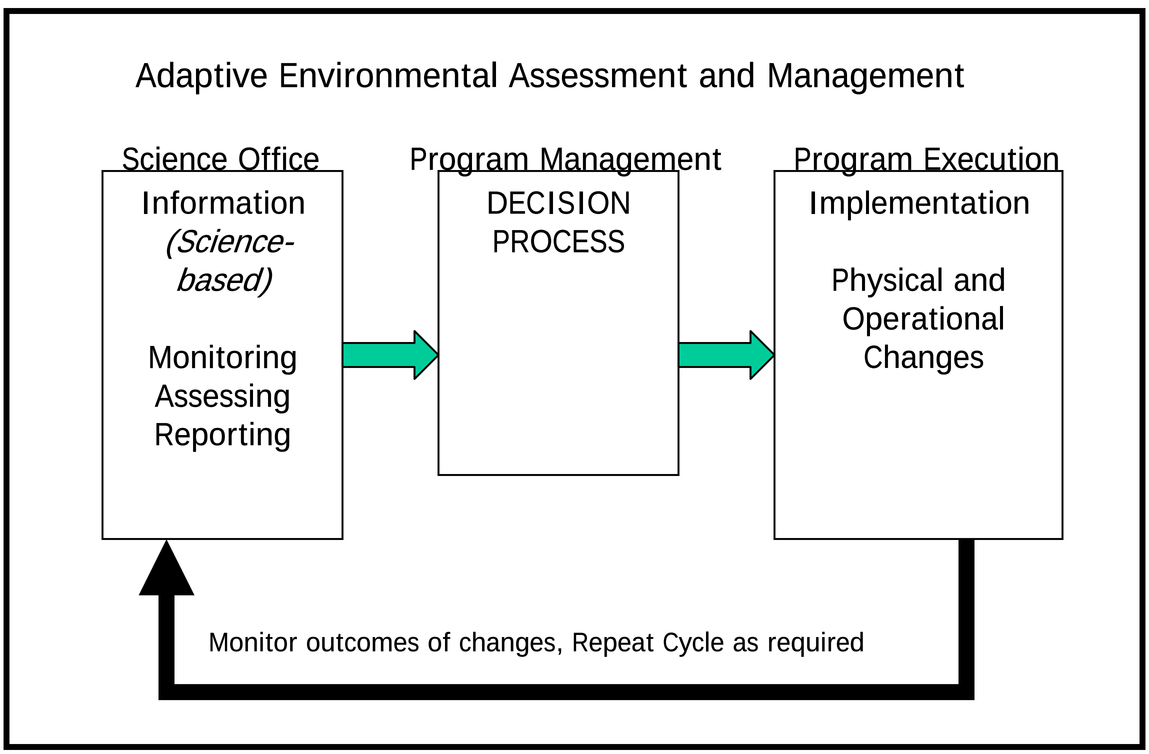

Figure A-2.1. Adaptive Environmental Assessment and Management. Different roles of the organizations and iterative steps are depicted here to illustrate implementation of an effective AEAM process.

The structures and general process outlined in the LCA S&T Program provide the basic elements of an adaptive management program. To make the AEAM effort most effective, it would be important to view the restoration effort as a learning process, with adaptation as required. Timely and effective communication of information to all participants would be instrumental in effectively implementing the AEAM process and to further attain program objectives. Examples of communication tools are project-specific assessment reports (report cards), annual programmatic AEAM report, and science symposia convened on an annual or biennial basis.

An AEAM framework would be used to help guide restoration actions toward a sustainable condition. The major components that comprise an AEAM framework are: goals and objectives, conceptual models, performance measures, role of targets, project and basin-level assessments, monitoring, modeling and research, information and communication frameworks, and decision-making approaches. A summary of some of the important AEAM elements is discussed below.

2.1.1 AEAM Elements

2.1.1.1 Goals and objectives

Goals and objectives for restoration in coastal Louisiana can be developed at a number of scales and are essential at all scales. At the programmatic scale, a coastwide vision for the future and a benchmark for progress can be formulated. At the project scale, goals and objectives are critical in design and evaluation. However, they may be used slightly differently at each of these levels. At both scales, the LCA Plan would improve current efforts to refine quantitative and measurable objectives.

The LCA program goal is “Reverse the current trend of degradation of the coastal ecosystem.” The objectives would present the approaches and actions to be undertaken, and if successfully completed would show progress towards achieving the goal. Progress towards a sustainable ecosystem would support nationally significant living resources, provide a diverse array of fish and wildlife habitats, and reduce nitrogen delivery to offshore gulf waters. Planned features that promote the distribution of riverine freshwater, nutrients, and sediments, using natural processes and ensuring the structural integrity of the estuarine basins, would accomplish these objectives.

2.1.1.2 Increase understanding using models

Models are useful in identifying attributes that provide a measure of the behavior of a broad suite of ecosystem properties and allow the selection of alternative courses of action during the rehabilitation project (Lee and Gosselink, 1988; Mitsch, 1994; Lee, 1993). In addition, models represent an important "cross-fertilization" (Shugart, 1989) between long-term monitoring and modeling. The S&T Program would develop interactive, spatially explicit models that allow the evaluation of simulated results of proposed management alternatives across the landscape as recommended by Meyer and Swank (1996). Capitalizing on differing areas of expertise, the S&T Office and the Program Execution Team would collaborate on the execution of models developed by the S&T Program. The suitability of those models to meet program goals would be conveyed back to the S&T Program for review, analysis, and subsequent refinement of the models. The introduction of a modeling component to a restoration program can help forecast the trajectories of success criteria in terms of hydrology, geomorphic features, ecological structure, ecosystem function, and landscape sustainability. Modeling plays a crucial role in AEAM to modify or adjust restoration programs or actions, and to provide analysis and guidelines as to the efficiency of different rehabilitation strategies (**figure A-2.2**). Modeling methods that were employed to guide the early LCA Plan formulation are described in detail in Appendix C, HYDRODYNAMIC AND ECOLOGICAL MODELING. AEAM relies extensively on the use of models to articulate understanding and forecast the effects of alternative management actions. Estimating the effects of a particular restoration action requires projections of the future outcome (i.e., system state) of a decision within the dynamic behavior typical of estuarine systems.

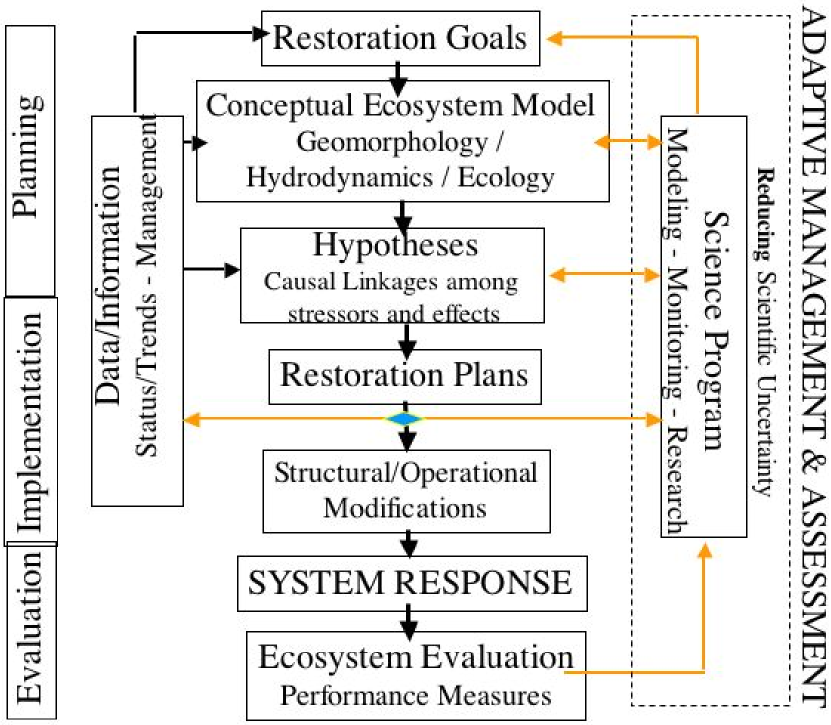

Figure A-2.2. Adaptive Management and Assessment. This figure presents the S&T Program Approach proposed for developing comprehensive ecosystem restoration plans for the LCA Plan (Adapted from Ogden, 1999).

Standard methods of model calibration and verification would be used to ensure that algorithms for critical processes are sufficiently robust to accurately portray processes in reference, forecasted, and existing settings. Standard methods of error and uncertainty analysis can estimate the robustness that managers can expect of model forecasts. After this step, the algorithm can then be applied to guide restoration with confidence that it can simulate not only the impacted condition but also the local reference condition. Post-construction assessments of the models are critical to determining the effectiveness of the models in predicting future outcomes. These assessments should identify hypothesis-driven research and data needed to support model refinement. The models provide assurance that the functions are accurately described and objectively simulated.

AEAM would not be conducted independent of other coastal activities; therefore, modeling efforts would integrate existing projects and permitted activities. Cumulative assessments of human induced and natural factors would be integrated into predictive tools. For example, Corps of Engineers water resource projects and regulatory activities (Section 404 permits) would be integrated into the hydrologic unit/watershed scale restoration plans.

2.1.1.3 Supporting research

An important element of any AEAM strategy is carefully planned and focused research. Testing underlying hypotheses of system behavior and model assumptions are integral components of supporting research. Research for the LCA Plan would be process oriented and focus initially on testing critical hypotheses developed from previous modeling efforts identified during the early LCA Plan formulation process (See Appendix C). It would also be necessary to build on lessons learned from other studies along the coast such as prior investigations at Caernarvon that suggest the potential benefits of periodically pulsing waters through that diversion. Numerous other hypotheses have been developed from lessons learned in previous studies during implementation of the early LCA Plan formulation effort. However, research would not be conducted solely to feed the needs of the models. Results must be focused on clearly meeting program execution. Sufficient information would be obtained to address critical questions, and the level of uncertainty associated with those answers must be clearly articulated to stakeholders. Supporting research would be directed at reducing scientific uncertainty to improve confidence in modeling and monitoring tools and ultimately management actions. Research would also undergo regular intense peer review to maintain the highest level of integrity.

2.1.1.4 Monitoring and evaluation

Scientifically defensible monitoring programs are critical to AEAM. Monitoring provides feedback between decision-making and system response relative to management goals and objectives. Monitoring characterizes actual system response to management actions whereas models forecast probable future system states. Feedback from monitoring and decision-makers into program goals, objectives and system understanding provides the information for "assessment" that enables the "adaptive" component of AEAM.

Informative monitoring programs would identify what is to be monitored to appropriately describe system state, in relation to management goals and objectives (Steyer and Llewellyn, 2000), and the questions that are important to management (Lee 1993). Monitoring program designs would be sensitive to tradeoffs in accounting for temporal and spatial variability, which may hinder traditional statistical and experimental design approaches (Underwood, 1994). Flexibility, therefore, would be incorporated into monitoring approaches to account for uncertainties in addressing system variability.

Monitoring also provides information for building effective models. Monitoring provides data for estimating initial conditions and parameter values of models used in support of AEAM. Monitoring results would also be used to describe and decipher differences between forecast and measured system response to management actions.

2.1.1.5 Data management

Management of data collected prior to the S&T Plan as well as data collected during implementation of the S&T Plan is critical to ensure establishment of "institutional memory" within the S&T Program. The LCA Plan is proposed to cover an extensive period, and therefore, makes it imperative that data are managed in such a manner that the S&T Program can build upon prior efforts. This requires that the process be transparent, i.e., open and available for public scrutiny, and that the data be available in a form accessible to all sponsors with limited but necessary controls. Prior studies would not be repeated due to the lack of this important element of AEAM.

2.1.1.6 Decision-making approach

The AEAM framework would be invaluable in assisting the LCA Program Manager to arrive at informed decisions that continuously seek to improve program performance. The process of making a decision largely consists of the gathering and analysis of information to support the choice of one among a number of possible alternative actions. The annual AEAM Program report prepared by the S&T Office for Program Management, and the Program Execution Team would serve to continuously update these forecasts and evaluations, facilitating sound adjustments to program and project-level efforts.

2.1.1.7 Learning and adaptation

Learning and adaptation are elements of adaptive management that close the feedback loop and initialize the next cycle of iterative management actions. Information from monitoring, results of experimental manipulations, model forecasts, and supporting research are combined to yield either confirmations of existing beliefs or new explanations of the factors that control the system. This vital information should be "learned" by all stakeholders. Over multiple iterations of the adaptive process, new understanding of how the system operates should result in the re-formulation of goals and objectives.

3.0 SCIENCE & TECHNOLOGY PROGRAM IMPLEMENTATION

All activities developed under the S&T Plan would be coordinated and approved through Program Management and responsive to the Program Execution Team. The S&T Program would provide analytical tools (e.g. hydrodynamic and ecological models) and frequently assess the effectiveness of those tools through close communication with the Program Execution Team. This section of the S&T Plan provides the goals and objectives of the S&T Program, the proposed organizational structure, including the S&T Office, and a discussion of the major functions of that Office. For each major function, a brief description is provided why that function is important, a short assessment of lessons learned where a similar function has been used in other ecosystem restoration efforts, and finally, the LCA approach to implementation of each function based on those lessons learned.

3.1 S&T Program Goals and Objectives

The goals and objectives of the S&T Program are to provide the necessary science and technology to effectively address coastal ecosystem restoration needs. The S&T Program would provide analytical tools and recommend to Program Management appropriate studies to ensure that current issues of uncertainties can be reduced by sound scientific investigations.

3.2 Organization

The main structural elements of the S&T Program and its relationship to Program Management are shown in **figure A-3.1**. It consists of four major components: The S&T Office, a Science Coordination Team, a Science Board , and ad hoc Peer Review Committees. The program would be flexible and would reach out to scientists within Louisiana, nationally and internationally, and would provide for direct communication with Program Management and the Program Execution Team.

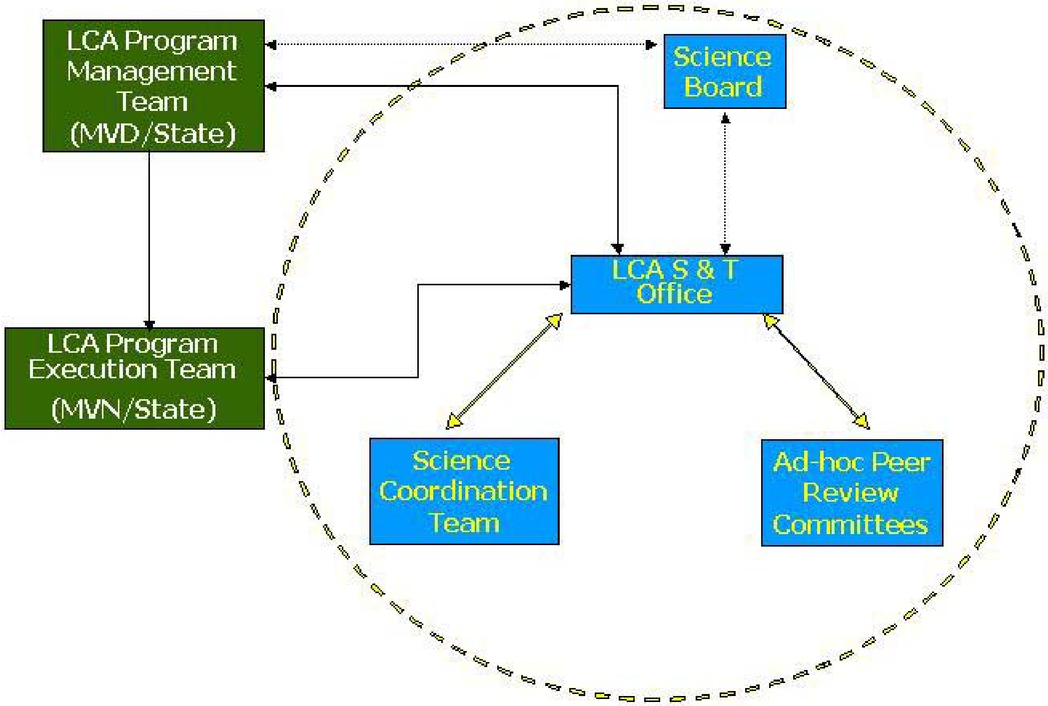

Figure A-3.1. S&T Program and Management. This figure presents the structure and lines of communication between the S&T Program, LCA Program Management, and the Program Execution Team.

3.2.1 Science & Technology Office

The S&T Office is the focal point for activities of the S&T Program. It provides a physical location and primary point of contact for all agencies and individuals with interests in science and technology. It must communicate regularly and efficiently with LCA Program Management and the Project Execution Team while maintaining a separate identity and independence from the day-to-day activities of implementation. The S&T Office consists of the Director, a deputy Director and a small support staff. Funds would be allocated to the Science Program by the Program Manager to support plan implementation by the Program Execution Team and to address programmatic-level science needs. For example, funds could be used to: 1) develop necessary scientific data and information to implement features found in the near-term course of action; and 2) fund coastal restoration science and technology proposals to address uncertainties related to enhancing system-wide understanding, engineering concepts, and operational methods (see Section 2.0).

3.2.1.1 The Director

The Director oversees the S&T Program and is responsible for the operation of the S&T Program and the conduct of all functions of the S&T Program. The Director is a member of the Program Management Team. Program budget request are prepared by the

Director in coordination with the Program Execution Team request and submitted to the Program Manager. A copy of the S&T budget request would also be provided to the Program Execution Team for consolidation of budget request of the program back to the Program Manager. The Director is a federal employee under the S&T Office and should meet the qualifications set by the Program Manager. More specifically, the Director should have:

- Experience in managing complex scientific programs and a variety of scientific disciplines,
- Undertaken substantial scientific research work in any field related to LCA,
- Experience managing environmental issues or advising high-level managers in methods for promoting science-based decision making, and
- A record of publication in the peer reviewed scientific literature.

The Director is appointed by and reports directly to the Program Manager. He/she is spokesperson for the S&T Program at all levels within the LCA structure and has responsibility for the conduct of the S&T Office and all functions of the S&T Program. The office of the Director should be a centrally located area of activity in Louisiana. The State recommends the Louisiana State University and A&M campus in Baton Rouge as the site of this office. This flagship university location is an appropriate site to best coordinate and execute the S&T Program.

The Director would be supported by a Deputy Director. The Deputy Director's responsibility would be to assist with the operation of the S&T Office and provide additional scientific expertise and background to the S&T Office. Other S&T Office staff would include administrative support (1 Full Time Employee (FTE)), fiscal planning and management (1 FTE), and contracting experts (2 FTE's). Depending upon the specific contracting mechanisms used to support Science and Technology Program activities it is possible that some science and technology contracting personnel, but not all, may be embedded with one of the LCA cooperating agencies.

3.2.1.2 The role of the science & technology office

It is expected that the Director would consult regularly with the Program Execution Team and utilize a number of different mechanisms and processes to achieve program goals. Where activities are delegated or contracted out, the Director remains responsible for the quality and integrity of the processes and products.

In general, the S&T Office coordinates, administers, and reports on science activities conducted as part of the LCA planning and implementation effort. It does not perform or manage the science studies. It is envisioned that specific responsibilities of the Director and the S&T Office would include:

- Develop an Annual S&T Plan and Report, to include updates/revisions to conceptual models that includes any necessary revisions of conceptual models regarding system function based on new science findings (from all credible sources),

- Ensure communication with the Science Coordination Team, the Science Board, Program Management, Program Execution Team, and other groups and organizations with interests in the S&T Program,
- Identify opportunities and recommend to the Program Management competitive funding mechanisms for some science and technology activities,
- Develop and implement Peer Review processes and mechanisms for the S&T Program,
- Establish a Knowledge Center or Clearing House for science and technology-related reports, documents, and publications,
- In association with the Program Execution Team, take a lead in the conception, selection, and design of demonstration projects and baseline studies that reduce scientific and engineering risk and uncertainties (see section on Scientific Uncertainties),
- Facilitate communication between S&T Program product developers and product users (e.g., Program Execution Team),
- Provide a framework for decision-making, which defines issues be clearly and technically defined, Work with scientists and managers to develop research projects that resolve scientific uncertainties that inhibit restoration planning, predictive modeling, and program implementation, Provide input to the Program Execution Team during the scoping phase of studies and preparation of engineering, design, and decision documents, Provide scientific data, analysis, and interpretation critical to the design, construction and operation of restoration projects as appropriate for the evaluation of ecological success of projects, and for the modification of existing or future projects when "success" is found to be limited,
- Recommend and execute, as appropriate, focused data collection and investigations to provide:
  - Studies to assess initial baseline and monitoring to document ecological conditions,
  - Demonstration project studies and continuing adaptive management,
- Develop data management and dissemination protocols to support system-level restoration planning and execution,
- Assess the immediate and long-term effectiveness of restoration actions in meeting program goals in concert with the Program Execution Team,
- Provide information and synthesis in a timely manner and useful formats,
- Provide input to external review groups, and
- Provide input for Adaptive Management activities.

3.2.2 Science Board (SB)

The Science Board (SB) will be a small group that meets periodically and is knowledgeable of the ongoing activities of the program. The SB would consist of the appropriate number of members depending on scope of particular review: Several

National Academy of Science-level academics (convened on a contract basis), in addition to a representative of the USACE (Federal lead agency), a representative of the State of Louisiana (Non-Federal lead), and a representative of appropriate additional Federal agencies.

Each member of the SB should hold high level scientific credentials (e.g., a Ph.D. in an appropriate field of science or engineering), have experience in science program coordination, and have a background in the science and technology issues surrounding coastal restoration.

The role of the SB is to periodically review the Science program and prepare reports providing recommendations and advice to the Program Manager and Director of the S&T Office. The purpose of these reviews and reports is provide an independent assessment of the program. The Director of the S&T Office will keep regular communication with the SB between formal review sessions. Additionally, the SB would:

- Review the LCA program to identify gaps in scientific information and adaptive management tools and strategies,
- Recommend tools, processes, and methodologies from a review of current research to improve ongoing LCA restoration efforts,
- Work closely with the Director to review recommended changes that are needed in the applied science strategies of the restoration program,
- Possibly recommend establishing new science initiatives, innovative restoration tools, and other challenging research and development issues, and
- Report to Program Management and the Director of the S&T Office regarding the effectiveness of science and technology program to meet the science and information needs of the restoration program.

3.2.3 Science Coordination Team (SCT)

The SCT would provide the S&T Program with a mechanism for coordinating LCA Plan science initiatives with ongoing and planned science activities being undertaken in state and federal agencies, under CWPPRA or other restoration efforts, and within the broader scientific community. The SCT members would assist with information transfer, planning periodic science symposia, and would advise the Science Director of new scientific developments and technological advances occurring within other agencies. The SCT would be an inclusive body with members representing federal, state and local governmental agencies with scientific interests, non-governmental organization (NGOs), academic institutions, and private interests. The Director would chair the SCT.

3.2.4 Ad hoc Peer Review Committees

All scientific investigations and project studies would be subject to a peer review by an independent panel of experts. The peer review may include a review of the economic and environmental assumptions and projections, project evaluation data, economic analyses, environmental analyses, engineering analyses, formulation of alternative plans, methods for integrating risk and uncertainty, and models used in evaluation of proposed projects.

3.3 LCA S&T Office Functions

One of the primary functions of the S&T Office would be to continuously identify areas of scientific and engineering uncertainties as discussed in Section 4.0 below, and design and execute studies to reduce those uncertainties. The S&T Office must also develop appropriate analytical tools and ensure product applicability for the Program Execution Team, and it must maintain regular and frequent communication with those planning, designing and constructing projects. Several related functions are discussed below.

3.3.1 Develop Analytical Tools: Hydrodynamic and Ecological Modeling and Assessment

3.3.1.1 What are models and why they are important?

Models are mathematical or conceptual approximations of systems that embody essential processes, functions, and structure of real systems. Conceptual and numerical models are pillars of AEAM for a number of reasons. Models can be used as a template on which knowledge about system processes and functions can be systematically organized, integrated, and updated through the feedback loop provided by AEAM. Used in this way, models become the dynamic archive for knowledge about system response to variability in driving variables, changes in input or outputs, or management actions. This dynamic archive should include all elements of the natural setting, the hydrologic cycle, and its ecological analogues and key processes must be considered over the range of time and spatial scales in which they naturally occur.

Three broad categories of models are possible, conceptual, physical and mathematical. Conceptual models can be used to organize information and develop a framework that qualitatively describes system function and process. Physical models may be used as a means of investigating the qualitative effects of large and small diversions of river water and sediment into the adjacent wetlands. Physical models can also be useful in conveying to the public and special interest groups a clear picture of alternatives under discussion. Mathematical models can be used as a surrogate for a system so that management actions can be tested and improved in a virtual context. This testing can include mathematically rigorous uncertainty and error analysis to identify model sensitivity to key variables. This knowledge may be used to refine or reorient monitoring and research activities and to develop risk-based decision-making procedures. Use of models as system surrogates helps avoid ineffective (and expensive) management actions and attendant negative impacts on high value natural resources. They may be used to forecast benefits and impacts of alternative actions as part of cost/benefits analysis and thereby help identify optimal restoration actions. Modeling results may also be used to develop mitigation plans to compensate for unavoidable impacts. They may also be used to develop and explore innovative solutions and approaches to restoration not possible with direct experimentation because of time, funding, or risk. Most important, simulation of long-term system dynamics using models can be used to evaluate the sustainability of management alternatives. This last use of models is particularly important when systems are restored to conditions for which historical reference conditions are unavailable. In this last case, numerical models provide the only means for evaluating the sustainability of management actions.

Numerical models useful for LCA restoration can be broadly separated into three categories by scale of application and discipline: natural resource/ecosystem models, engineering models, and socio-economic models. Natural resource and ecosystem models attempt to understand, quantify, and integrate patterns of biotic responses to trends of climatic variability, geological framework and evolution, watershed and groundwater hydrology, physio-chemical properties of soils, hydraulics and hydrodynamics of rivers, estuaries, and the coast, sediment transport and deposition, salinity, and water quality. Engineering models for LCA restoration focus on those portions of the ecosystem that constrain or would be directly altered by the siting, sizing, construction and operation of diversions designed to prevent wetland loss. Engineering models address water and sediment yield, local subsidence, geologic faulting, depth of water in the receiving area, proximity of the river to the receiving area, exposure of the receiving area to storm surges and waves, infrastructure affected by the diversion, and similar factors. Socioeconomic models link economic value to biological and physical processes so that management actions can consider risks of coastal land loss to billions of dollars in market-based resources and infrastructure. Socioeconomic models would integrate social sciences with physical and ecological sciences to forecast responses of human populations and activities to restoration action. It is important that all three types of models utilize the same modules to simulate processes that are common across two or more modeling categories. Ultimately, all three types of models must be used as an integrated tool to develop and support a biophysical environment that sustains both human and natural communities.

3.3.1.2 The LCA approach

Annual (or more frequent) internal meetings would facilitate communications among modeling teams and publication in the peer review literature would be encouraged. Provision in the program structure is made for modeling team members to coordinate with modeling teams supporting other large ecosystem restorations. Provision is made in the program structure for communication between monitoring and modeling functions.

In addition to the broad approaches listed above, the LCA approach would include the following more specific elements. First, the modeling approach used in LCA would respect the diverse conventions and traditions employed by the different disciplines that typically engage in restoration modeling. That is, modeling approaches would be used that integrate the tools of the different disciplines in a way that maintains the fidelity of the guiding principles of each discipline, particularly the way that the different disciplines incorporate scale in their tools. By so doing, modeling tools developed by the LCA S&T Program would be able to adequately simulate the many different wetland processes that occur over a wide range of scales. Models would be developed by the S&T Program jointly with the Program Execution Team to ensure product utility and the Program Execution Team would use those models. The Program Execution Team would then provide feedback to the S&T Program for refinement. This process of development, application, and refinement would be an integral part of the entire S&T Program.

3.3.2 Data Acquisition, Scientific Investigations, and Monitoring

Models described above can help guide restoration and management decisions. However, models are only useful if they are driven by high quality data and accurate assumptions about ecological relationships. Monitoring provides the data that models use, and scientific investigation analyzes the accuracy of the assumptions and functions used in the models. Given the high level of scientific uncertainty involved in restoration activities of the magnitude planned for LCA, both components are critical to accurate modeling. In addition, only through effective data acquisition, monitoring, and focused, applied research can the "success" of restoration or need for modification of management actions be elucidated. LCA implementation would affect the entire coast of Louisiana; therefore it is essential that data acquisition and monitoring be conducted on the project-specific, basin and system-wide scales. Monitoring and research designs should be nested to support long-term, large- scale status and trends and short-term question-specific monitoring at the project level. The data would characterize baseline conditions (physical, chemical, biological, socio-economic, etc.) necessary to evaluate changes in trajectories of critical processes and conditions over time. These baseline data are essential to monitor changes as they are affected by LCA projects. Data would be utilized to assess LCA performance measure targets, assess system responses, and improve conceptual and predictive models and working hypotheses.

3.3.2.1 Lessons learned from data acquisition and monitoring systems in restoration

The United States General Accounting Office (GAO) in 2003 conducted assessments of comprehensive ecosystem restoration programs that included specific recommendations regarding monitoring (GAO-03-345 and GAO-03-999T). In these programs the GAO found that a comprehensive monitoring plan was lacking, prohibiting the ability to comprehensively assess restoration progress. Further, they found significant data gaps and the lack of consistent, reliable information and measurement indicators. Without a comprehensive monitoring plan based on key indicators, the GAO suggests that the ability to understand how an ecosystem responds to restoration actions would be severely limited and that decision-making using an adaptive management framework would be greatly hindered.

Louisiana initiated a wetlands monitoring program in 1990 to evaluate the effectiveness of individual CWPPRA projects, concentrating on physical and biological variables specific to project goals and objectives. While project-specific monitoring was effective at assessing small-scale projects, it was not comprehensive enough to evaluate cumulative effects on a larger basin or coast-wide scale. The CWPPRA monitoring program has evolved to a more programmatic approach by implementing in 2003 the Coast-wide Reference Monitoring System (CRMS – *Wetlands*), which is a robust system-wide monitoring design to facilitate the evaluation of physical, biological, and landscape variables across larger temporal and spatial scales. CRMS-*Wetlands* focuses on key system indicators that would provide data necessary to conduct comprehensive wetland assessments, refine conceptual models, and support an adaptive management program.

3.3.2.2 The LCA approach

Results of data acquisition and monitoring would be used to evaluate the effectiveness of individual projects, to assess LCA's progress towards meeting program objectives, and to identify opportunities for improving LCA implementation. LCA conceptual models of ecosystem functions have produced working hypotheses of how the system would respond to management actions over space and time. The working hypotheses are based on the current understanding of the causal factors that have led to the deterioration of our coastal landscape. The conceptual models provide the rationale for identifying performance measures, and a framework for selecting variables to be measured to document status and trends of ecosystem properties.

A proposed system-wide assessment and monitoring plan (SWAMP) would be developed that incorporates existing monitoring efforts (to the extent possible) within a system-wide experimental design. The SWAMP would integrate monitoring of biological, chemical, physical and climatological variables in four modules: wetlands, barrier islands, inshore waters and rivers, and near coastal waters (hypoxia). The variables monitored would include those necessary to assess performance measures and to document the long-term restoration of LCA ecosystems. The first of these modules, wetlands, was designed under the CWPPRA monitoring program (CRMS – *Wetlands*, Steyer et al. 2003). It describes linkages to project-specific and system-wide objectives, reference site issues, statistical design, monitoring variables, sampling design, and implementation criteria. This framework is currently being used as a template for inland waters and rivers and would also be used for the other modules.

In addition, baseline, project specific, and broad-scope research projects would be undertaken to discover and analyze those ecological and biological processes that would likely be affected by LCA project activities. Research projects would address questions of community dominance, populations of rare or listed species, component food web, etc. in order to ascertain likely effects of river diversions, sediment additions, nutrient regime changes, etc. on the component biota. These results would be used to refine model assumptions and functions, and the data and ensuing model outputs would help guide management actions. As models are prepared under the S&T Program, they would be provided to the Program Execution Team for implementation. The Program Execution Team would then provide recommendations for improvements back to the S&T Program.

This iterative process of building, applying, and refining would continue as each model evolves.

3.3.3 Data Management, Computing and Information Framework

3.3.3.1 Why is information technology important?

The LCA restoration process would include data collection, development of modeling and assessment tools based on those processes, development of decision support tools for evaluating project alternatives, and publishing data, analyses, and plans for end-users in and out of government. An enormous amount of data would come in different formats from different organizations and must be organized and integrated into forms that are widely accessible and useable. It is critical that scientists, engineers, and managers from a variety of disciplines and organizations be able to operate in a collaborative environment. A well-conceived computing and information framework is key to this success and should be constructed by appropriate scientist, resource managers in conjunction with IT personnel.

3.3.3.2 The LCA approach

The computing and information framework needs of such ecosystem management projects have given birth to an entirely new field of science (informatics). Informatics is becoming the enabling technological structure upon which hydrologic, geotechnical, and biological developments are being based. Informatics technology areas (ITAs) are presented below:

- *Integrated Frameworks.* Integrated frameworks provide a common technology structure to deliver information and technology. Establishing commonalities in the technical architecture of LCA science and technology tools and systems would improve usability and interoperability as well as reduce the total cost of the product. Frameworks should exist for multi-dimensional models, geospatially-driven decision support tools, and for web-delivered products.

- *Data, Data Fusion, Aggregation, Management, and Mining.* This ITA focuses on a common set of methodologies that locate, collect, manipulate, describe, and use data in support of LCA business processes. The effective use of data requires establishing a formal database structure, data models, and the consolidation of disparate information sources for the purpose of discovering useful information and ultimately for driving higher-level informatics tools.

- *Modeling and Assessment.* The ability to develop and apply modeling and assessment (M&A) tools is critical to the success of LCA. Models and assessment tools would be used to simulate various physical, chemical, and biological processes, in multiple time and space scales, on numerous computing platforms. It is important to understand from the beginning how computational S&T would be conducted and on what computational infrastructure (networks, computers, mass storage devices, etc.). Much time and funding can be saved through improved coordination of model development activities within and across application areas.

- *Decision Support.* Decision support is viewed as the set of capabilities that synthesize and present information that directly aids the decision process. These capabilities complement the GIS/CADD and M&A ITAs by infusing their results into the decision process. In many cases, decision makers cannot directly use GIS/CADD and M&A-derived information. In such cases, screening tools, low-fidelity models, data converters, analytical methods, and visualization techniques translate the information to feed a collaborative decision process. The technology required to provide decision support to decision makers should be minimized to decrease the training burden on the user base. Ideally, decision-support capabilities would be distributed via the Web, thereby requiring no more than a simple Web browser to access the decision-support capabilities.

- *GIS/CADD.* The pervasiveness of spatial data throughout the S&T community motivates the need to collectively address GIS/CADD. Standards (e.g., data models) emplaced within the GIS/CADD area allow S&T tools to share and reuse GIS/CADD data and the supporting functionality to visualize, manipulate, analyze, and display geospatial information. The ability to expand modeling and decision support into 2- and 3-dimensional space/time, as provided by geospatial technologies, would tremendously enhance the products available to LCA. Common data standards must be agreed upon, and used to achieve technical and financial rewards.

- *Data Centers.* Data in LCA would exist in three general forms 1) geospatial, 2) scientific, and 3) multi-media. The underlying technology used to store, manage, and share this information is critical to the success of LCA and thus, an early goal for the LCA Science and Technology program would be the establishment of one or multiple LCA Data Centers. The Data Centers' function is to be repositories of geospatial, scientific, and multimedia information housed to aid LCA. It may be most practical to have multiple Data Centers, perhaps responsible for different data types, as long as a central authority makes sure that all of the Centers interoperate efficiently.

All of the models, tools, and Websites should be provided in a secure environment that allows access to appropriate parties but is consistent with computer security requirements of the stakeholders. Security would be important in every computing and information framework activity, and as a result, would require detailed implementation plans. These plans would require discussion and agreement between the cost-sharing partners and appropriate stakeholders.

Given the number of organizations and disciplines involved in LCA, it would be useful to have a computing and information framework group to ensure that the products developed provide the necessary functionality to accomplish the purposes of LCA. The group should meet periodically to exchange information and discuss necessary adjustments that could occur, given the rapid pace of technology change in this field.

3.3.4 Decision Support

3.3.4.1 Why decision support is important?

Decision support describes the framework and process used to integrate analysis with decision-making, and represents the primary purpose of the Science Plan. The Plan seeks to help decision makers to make the best possible decisions about the design and implementation of LCA Plan projects in the face of uncertainty, and to reduce uncertainty over time in order to improve future project planning and decision-making. The challenge for the Science Plan is to develop a decision support framework that incorporates scientific approaches directly into the LCA Plan planning and implementation process. By definition, science is the process of continuing inquiry. Decisions to pursue some actions must be made, but there is a need to continually apply science as a process in order to minimize the likelihood of future errors. Indeed, we act in part in order to learn, and this learning helps to improve our models of the system so that future actions are better able to define and achieve desired goals. Learning while doing is what it means to take a science-based approach to the LCA Plan.

In recognition of pervasive uncertainties, the Science Plan incorporates adaptive management as its central organizing theme and operational process. Adaptive management is more than a description of how we would learn about the natural ecosystem and its links to ecological and socioeconomic outcomes; it can also help guide how projects in the LCA Plan would be formulated, selected and implemented in a sequence over time. Presumably, what we learn from successive rounds of project planning and implementation could cause us to rethink the operation of already implemented projects and the design of future projects, as well as to adjust the Science Plan and supporting analytical models to better inform future decision-making.

3.3.4.2 Systems-scale synthesis model for decision support

LCA projects are expected to work synergistically to serve program goals and meet program constraints. This means that the ideal LCA Plan would be a system of projects built incrementally and then operated in consideration of other projects in place and being planned at the same time. The decision support framework should organize the suite of LCA analytical efforts in a way that supports this systems nature of LCA. This can best be accomplished through the development of a “systems synthesis model” that provides the means to systematically consolidate and connect ecosystem modeling with evaluations of ecological and socioeconomic outcomes of interest to decision makers. Such a systems synthesis model would be used to rapidly simulate the multiple outcomes of various combinations of projects/alternatives while identifying the logic and assumptions underlying these predictions and their role in decision-making.

The purpose of the systems synthesis model is to help decision makers to expedite the evaluation of tradeoffs to support decision-making on incremental investments. In the LCA Plan, where decision-making is expected to be an open process, the desired contribution of the systems synthesis model to decision support requires that the assumptions, computational techniques, and the logic underlying model results are transparent to all. The USACE Institute for Water Resources has promoted this approach as part of its “shared vision planning” model. That model or some other “computer aided decision support system” would be adapted for decision support in the LCA context. The usefulness of augmenting the system synthesis model with “multi criteria decision analysis” techniques could help decision makers and stakeholders to explore tradeoffs, reveal priorities, and highlight areas of agreement and disagreement in order to facilitate deliberation and decision-making.

An important role of the systems synthesis model is to help identify and prioritize key uncertainties in order to inform the design of demonstration projects and experiments that can help reduce uncertainties over time. The ultimate use of the knowledge gained is to improve the predictive accuracy of the model for use in future rounds of decision-making. This means that the systems synthesis model must a have a clear process and capability to use what is learned in order to make model improvements over time so that subsequent rounds of decision-makers are better informed. For example, while the systems synthesis model must be empirical, best professional judgment or literature values could be employed where there are significant uncertainties in data or in relationships among variables in the model. The representation of such judgments in a “Bayesian” framework could allow the model to be solved, the propagation of uncertainty into the model prediction to be represented, and critical uncertainties to be identified as a way to target the adaptive management studies for model improvement for the next round of decision support. The Bayesian approach as well as other methods for conducting sensitivity analysis on parameters and data characterized by high levels of uncertainty would be investigated.

3.3.4.3 Environmental and socioeconomic evaluations

Formulating and evaluating incremental actions for the LCA Plan, and then informing the decision on the best mix of such actions in any planning round, is the challenge that can be addressed by a system-level evaluation process. At the heart of system-wide evaluations are spatially–robust predictions of hydrodynamics, landscape evolution, and water quality. Predictions of these basic “ecosystem effects” in turn inform predictions of multiple ecological and socioeconomic outcomes of concern to decision makers.

Metrics for measuring these multiple ecological and socioeconomic outcomes, linked to predictions of ecosystem effects, are necessary if the modeling efforts are going to inform the deliberations of decision makers. Ecological outcomes, represented in non-monetary metrics, most closely reflect the specific outcomes of concern to decision makers and can be linked to predicted ecosystem effects with an acceptable level of certainty. For example, the LCA Plan may have a primary interest in securing certain species numbers and composition at a certain location. To the extent that predictive uncertainties can be adequately represented, predictions of species populations would be pursued. If, however, critical uncertainties in predictions of the state of the species cannot be identified and represented for decision makers, then the evaluations might alternatively rely on predictions of habitat suitability for the species that could be made with greater level of certainty.

In the case of socioeconomic outcomes, it could be possible to link predictions of ecosystem effects to the full range of these outcomes as represented in monetary terms. The LCA Plan could affect a wide variety of traditional "national economic development" (NED) outcomes such as navigation and flood control, as well as NED effects relating to industry and commercial and recreational fisheries. The goal of socioeconomic evaluation would be to estimate the aggregate net NED effects of restoration actions associated with all socioeconomic outcomes, including implementation costs. At the same time, NED evaluations must characterize the distribution of net economic effects so that tradeoffs between different economic sectors are fully represented for decision makers. For example, restoration actions that increase the salinity of waters in some location may result in NED benefits for certain fisheries while imposing NED costs on the oyster sector. Decision makers must be provided with estimates of these individual components of NED effects so that economic tradeoffs are fully considered in decision-making. Socioeconomic assessment would follow the procedures and methods set out in the *Principles and Guidelines* (P&G), as augmented with methodological refinements and developments made since the P&G was published, as well as with methods for addressing non-traditional NED.

Socioeconomic assessment would also pursue the evaluation of regional economic development (RED) effects representing local and regional economic outcomes. RED assessments would focus on estimation of both monetary effects (e.g., income) as well as non-monetary effects (jobs). Finally, various methods and metrics would be developed and used to assess social and cultural effects relating to, for example, community disruption and cohesion.

3.3.5 <u>Peer Review</u>

3.3.5.1 Why peer review is important?

The more complex restoration activities become, the more uncertainty is associated with their outcomes due to limitations in understanding, data availability or analytical procedures. Peer review of science and technology products, and program operations, can improve the technical quality and scope of the products and procedures as well as adding credibility to the conclusions and recommendations presented (NRC, 2002). In the case of coastal Louisiana, incorporating peer review as a routine part of S&T Program operations is essential for a number of reasons:

- The complexity of the ecosystem problems and the multiple possible solutions means that the solutions are not always obvious. Peer review can assist in verifying that approaches are broad in scope and that a considered process has been used to identify restoration actions.
- Peer review can provide assurance that the studies informing restoration decisions are reflecting the continual evolution of procedures in science and technology, and that methodologies are both current and appropriate.
- An independent verification of the quality of S&T Program products provides ongoing credibility to the restoration program as a whole, and provides valuable resource information for periodic reviews at the program level.
- Peer review is a widely recognized mechanism for quality assurance in technical studies and its use within the LCA program throughout the planning and implementation process would contribute to a wider understanding of how the technical opportunities and challenges implicit in such an ambitious program are being handled.

3.3.5.2 Lessons learned on using peer review in ecosystem restoration

There have been several recent evaluations of the use of the peer review in science and environmental planning (e.g., Kostoff, 1997; NRC, 1998). Most recently and most directly relevant to LCA planning are the National Research Council report on 'Review Procedures for Water Resources Project Planning' (NRC, 2002) and the draft report of the Chief of Engineers Environmental Advisory Board (EAB) on Independent Scientific Review both of which examined existing procedures and experiences in ecosystem restoration programs. Some key points from the documents are summarized here.

The EAB assessment of the peer review processes notes that a guiding process for peer review that is accepted by all participants is essential. This process needs to ensure that the subject matter of the review should be clearly identified and should provide for sufficient time, funding, and background information for the process to succeed. The process should also have iterative feedback loops that permit communication between the reviewers and the originators of the items under review. While disagreement may remain between reviewers and authors of the reviewed items, the process must be accepted as a fair approach to revealing legitimate differences in professional opinion. The EAB also notes that an external body to convene a review panel noting that there were two important criteria – objectivity and timeliness. Selecting the review panel, with an independent or neutral organization interviewing the prospective panelists to determine their interest, availability, and qualifications to gage their objectivity.

Importantly, the NRC noted that the role of review panels is not to present a final judgment on whether a project should be implemented NRC (2002). NRC suggests that an independent body oversee reviews, and that reviewers should be neither selected by nor employed by the Program Execution Team. Importantly, supporting this observation the report also recommends that the decision regarding the degree of a reviewer's independence should be open to review by all interested parties.

Both NRC and EAB note that peer review can be most effective in complex issues when incorporated early in the process, and that accountability is best assured by requiring written responses to the reviewer's observations and comments. For the above reasons, the S&T Office would manage certain aspects of the review of LCA execution.

3.3.5.3 The LCA approach to peer review

It would be the responsibility of the Science Director, working with the Science Board, to develop clear procedures for peer review for products of the S&T Program and the Project Execution Teams that may be adopted by LCA Program Management as a Policy to guide peer review throughout the LCA effort. It is expected that these procedures would provide for different approaches to peer review being used for different types of products NRC (2002). Note that risk and magnitude criteria can be helpful in determining the level of peer review appropriate for different products and efforts (Figure 4-2, page 45 in NRC, 2002). It is also expected that the LCA peer review policy would consist of two levels, which follow:

- Review of specific work products or reports. This part of the Policy would detail procedures for review of different types of products and identify procedures for review initiation, review process, reviewer selection, review feedback and tracking, and transmittal of review findings to decision makers. The process would be designed to be both responsive to program needs and objectives. The process would likely incorporate a combination of ad hoc review boards (e.g., by program function), reviews by selected individuals, and specially constituted review panels.

- Review at the Program level. It is anticipated that LCA Program Managers would initiate periodic reviews of the S&T Program, as well as other major Program elements. For instance, the NRC may be asked to review aspects of the S&T Program once the Program has developed sufficiently for a record of activities and products to be established. The Policy would identify principles to be followed during these periodic reviews and provide guidance to management regarding the frequency and direction of such reviews.

- Peer review on all future scopes of work that the S&T Program has developed will also be included. The LCA Program Managers would coincide with the peer reviews and address major Program elements. The future scopes of work would help identify any future, potential problems not foreseen within the LCA Program Execution Team.

4.0 SCIENTIFIC & TECHNOLOGY UNCERTAINTIES

4.1 Incorporation of Uncertainty in Plan Formulation

This discussion on Science and Technology uncertainties is intended to illustrate that considerable information has been developed from prior studies but data gaps still exist and considerable scientific and engineering uncertainties remain. The LCA PDT recognizes those uncertainties and has formulated a plan with this recognition. Largely based on knowledge gained from research in the coastal zone and restoration projects constructed the past 10 years under CWPPRA, the LCA PDT has identified a number of restoration features where uncertainties are limited (low risk). These features are given further consideration for implementation in the near-term with an imbedded adaptive management monitoring and assessment program. For those restoration features where science and technology uncertainty is deemed to be extensive (high risk), the feature presents the opportunity for implementation of an appropriately scaled demonstration project that serves to resolve the uncertainty. The S&T Office would serve an important role in both the adaptive management of near-term restoration projects and in the engineering, design, and later adaptive management of the demonstration projects. The discussion that follows details the different broad types of uncertainties, with appropriate actions to resolve them during LCA Plan implementation. A more detailed discussion of this plan formulation process is in Section 2.6 of the Main Report.

4.2 Types of Uncertainty and Resolution Strategy Within the LCA Plan

There are numerous types of uncertainties to be addressed to support and improve LCA restoration efforts. Each uncertainty requires a different resolution strategy, based on the effects of the uncertainty on the program, degree of uncertainty, cost of addressing the uncertainty, and importance of reducing the uncertainty. Some of the known and most relevant uncertainties associated with the LCA Program are listed below, grouped by type of uncertainty. This summary also reflects the types of uncertainties and engineering challenges inherent in large-scale coastal restoration efforts and potential strategies to resolve them.

4.2.1 Type 1 - Uncertainties about Physical, Chemical, Geological, and Biological Baseline Conditions

The existing knowledge base regarding baseline conditions is sufficient (low uncertainty) to facilitate construction of many of the restoration features evaluated in the LCA Study. Continued improvement of tools and networks to better document these baseline conditions would allow for more detailed and coast wide monitoring and assessment, which would better support program-level, as well as project-level, adaptive management. Some examples of basic baseline information needed to reduce scientific uncertainty include accurate measures of bathymetry of coastal environments and rates of subsidence and sea level change. Accurate measurement of bathymetry and geomorphology of the coast have a profound influence on hydrodynamic model outputs and the sensitivity of many ecosystem models. Some specific examples of uncertainties and potential investigations designed to reduce the uncertainties are discussed below.

4.2.1.1 Determine relative sea level change and the processes that contribute to the overall rate of change within the coastal zone

Accurate elevations across the coastal zone are necessary for documenting and modeling subsidence and sea level change. Processes that contribute to subsidence include, but are not limited to, consolidation, faulting, fluid withdrawal, and regional tectonic movement. Considerable work to address these processes has been done for specific locations of the coast.

In 1996, as part of the Morganza to the Gulf Feasibility Study, a contract report was prepared entitled “Datum Epochs, Subsidence and Relative Sea Level Change for Southeastern and South-Central Coastal Louisiana.” In 1995, the Barataria-Terrebonne National Estuarine Program (BTNEP) gathered elevation data in the Barataria Basin and Terrebonne Parish to evaluate subsidence rates. These data were compared to those in the feasibility report and a 1987 USACE funded report entitled “Terrebonne Marsh Subsidence Study”. Based on these data sources, for base conditions, apparent subsidence was assumed to be 0.54 ft (0.036 ft/year for 15 years) for all areas except “unhealthy” marsh areas, as identified in the BTNEP. “Unhealthy” marsh was assumed to subside a total of 0.74 ft (0.048 ft/year for 15 years). For future conditions, apparent subsidence was assumed to be 2.34 ft (0.036 ft/year for 65 years) for all areas except for unhealthy marsh areas where a value of 3.12 ft (0.048 ft/year for 65 years) was assumed. Subsidence is expected to magnify flooding problems for Terrebonne and Lafourche parishes in the future.

Although these studies provide valuable insight to subsidence rates in selected areas of the coastal area, other portions of the coast are not as well characterized. Currently, local, state, and Federal agencies, as well as private industry are working closely with the National Geodetic Survey (NGS) to establish a network of NGS High Accuracy Reference Network (HARN) monuments, NGS horizontal control monuments, and NGS vertical bench marks using GPS equipment to determine accurate horizontal and vertical positions relative to North American Vertical Datum of 1988 (NAVD 88) to meet the standards set forth by NOAA. Once the GPS corrected elevation data are adjusted, the benchmarks would be published by NGS. This network of benchmarks would be used to help determine the processes contributing to site-specific areas across the coast and the rates of subsidence. This information is a critical component to future modeling efforts, which would influence future project design, cost, and success.

4.2.1.2 Collect detailed bathymetric data throughout the coast

Information from the studies discussed above for subsidence also provides valuable insight into the bathymetry of segments of the coastal. Several of the LCA Study modeling tools and most future numerical models require detailed bathymetry to compute water depth and other wetland characteristics, but these data are currently not available throughout the coast. There is a need to rapidly and accurately depict coast wide bathymetry and regularly update the data to reflect changes due to sea level change, erosion, and sediment transport. The need is especially critical in the shallow, interior lakes and bays where data are difficult to collect.

4.2.1.3 Collect detailed topographic data throughout the coast

Several of the LCA Study modeling tools relied on, and many future modeling efforts will require detailed topography to compute water depth, duration and frequency of inundation and other wetland characteristics. However, these data are currently not available throughout the coast. Application of technological advances such as LIDAR would allow for rapid and accurate depiction of coastal topography. To be most useful, these data would need to be regularly updated to reflect changes caused by sea level change, subsidence, erosion, and sediment transport.

4.2.1.4 Determine sources of material (sand, silt, and clay) to meet needs of restoration efforts

While much is known about the location, quantity, and quality of material available for use in restoration efforts, additional and unknown sources of material may be suitable and available. LDNR is currently working with MMS to develop a central database of known sand resources. Existing data are being used to develop a plan for additional data collection including high resolution seismic, cores, and geologic mapping. This data would support modeling efforts to address sediment transport and linkages between nearshore and offshore environments.

The transport of sediment to be used onshore can be obtained from such sources as the Mississippi River. The quantity and quality of these resources (sand, silt, clay, nutrients, water) are also available for restoration efforts. The USACE and USGS have collected hydrologic stage and discharge data for the Mississippi River and its distributaries for many years. There is a general understanding of the amount of flow volumes down both the Mississippi and Atchafalaya channels. However, a detailed analysis of the seasonal availability and qualities of the water/sediment stream are necessary to make strategic decisions about resource allocation within the system.

4.2.1.5 Establish a coast wide network of monitoring stations to support understanding of natural variability, reference conditions, performance measures, and provide a database upon which future modeling efforts can be built

Through CWPPRA, a Coast wide Reference Monitoring System (CRMS) is being established to more closely monitor the effectiveness of restoration measures on reducing wetland loss along the Louisiana coast. Additionally, a CRMS coastal waters monitoring program and a Barrier Island Coastwide Monitoring (BICM) program are also being developed. Networking the CRMS and BICM to function as one comprehensive monitoring program would help addresses network needs to focus on all major ecosystem components. A monitoring database and network that addresses physical, geological, biological, chemical and landscape components and/or processes of the ecosystem would be beneficial. Information derived from these studies would also address Type 3 uncertainties described below.

4.2.2 Type 2 - Uncertainties About Engineering Concepts and Operational Methods

There are several engineering techniques and operational approaches that could potentially enhance wetland restoration. However, associated technological uncertainties with the techniques and approaches warrant further investigation. For example, there exists a capability with currently available dredging technologies to transport sediments long distances through pipeline conveyance. There is also a high degree of uncertainty about the availability of sufficient quantities of sediment resources and the sustainability of those resources.

In addition, uncertainties exist regarding the manner in which sediment materials can be properly discharged and dispersed to promote the establishment of new marsh vegetation while minimizing damage to existing marsh. Several of these uncertainties, and the potential investigations designed to reduce them are discussed below under Potential Demonstration Projects.

4.2.3 Type 3 - Uncertainties about our Scientific Understanding of Ecological Processes, Analytical Tools, and our Ability to Predict Ecosystem Response to Human and Natural Disturbances

Although numerous scientific studies have been conducted within the coastal environments, a considerable degree of uncertainty remains about ecological processes. Limitations in analytical tools to assess ecosystem responses also exist. Information obtained during baseline monitoring can be integrated into understanding ecological processes. For example, processes that influence land-water exposure also have a significant influence on the ability to accurately compute land loss rates. Ecosystem models developed and calibrated with data collected for baseline conditions and from monitoring efforts can be used to refine model outputs. Some examples of potential studies to address these uncertainties are provided below.

4.2.3.1 Develop a coast wide network of monitoring stations to support understanding of natural variability, establish reference conditions, assess performance measures, and provide a database upon which future modeling efforts can be built

This effort can address Type 1 and Type 3 uncertainties as discussed above.

4.2.3.2 Develop process-based models for prediction of land-building response to restoration measures

Models used to support LCA planning were developed and are discussed in detail in Appendix C. These models served as useful tools for evaluating restoration alternatives along with ecological benefits using a combination of modules that predict changes in physical processes and geomorphic features, and ecological succession on a basin-level scale. While these tools were useful, refinement of the models and the incorporation of additional data, once it becomes available, would help reduce uncertainties. The incorporation of inorganic and organic components of the land-building process would be an important aspect in the refinement of the models. Current modules have been based on natural analogs from the Atchafalaya and Wax Lake delta that are of an inappropriate scale for application to many proposed restoration measures. Incorporating organic production into a land-building module would facilitate linkage with a habitat switching and production module.

4.2.4 Type 4 - Uncertainties Associated with Socio-Economic/Political Conditions and Responses

To date, the vast majority of modeling and assessment in support of the LCA Study has been derived from the natural sciences e.g., geology, ecology, and engineering. Though most of these studies are predicated on NER-based justifications and project costs, socioeconomic research is, by comparison, limited. Lack of economic linkages to biophysical processes limits the ability to assess direct risks of coastal land loss to dollars in market-based resources and infrastructure. As part of LCA Plan Formulation an economic linkage study and an economic impact assessment study were commissioned. While these studies developed estimates of economic impacts within the coastal area for “Without Project Conditions,” more analysis would be required to detail NED costs and benefits at the project-specific level. To rectify this situation, socioeconomic modeling and assessment could be used to guide LCA Plan implementation.

Social sciences should be integrated with physical and ecological sciences in the planning and management processes, and by including the public as active participants in the planning and implementation process. The following examples are part of the strategy to resolve the socio-political conditions and responses.

4.2.4.1 Spatial analysis tools such as socioeconomic GIS layers, and integrated models should be used to factor human uses of the environment into the analysis of ecological variables

To incorporate social issues throughout the life of the Science Program, secondary census data trend analyses are needed to predict how social, cultural, and economic impacts may change over time. Trend analysis would also address the issue of how community interests fit with physical restoration efforts.

4.2.4.2 Economic impact and linkages

Input-output models can be used to determine how changes in particular sectors of the economy would affect the entire economy. Location Quotient Analysis describes how the local economy of a specific region compares to the national economy. Shift-Share Analysis clarifies how the shift in a share of a particular industry reflects on the local economy of a particular region. Research-based Benefit-Cost Analysis could prove complementary to internal analysis and serve as a check against the premature limitation of restoration options resulting from institutional bias and inadequate calculations of social costs and benefits.

4.2.4.3 Economic risk assessment

Stochastic modeling could also be used to calculate the level of economic risk associated with landscape responses to various climatic probabilities (i.e. hurricanes, sea level change, and drought).

4.2.4.4 Sociology and anthropology have multiple research tools that could be used effectively in the LCA study

Surveys can be used to extract preferences for restoration alternatives at the local and parish level. Community modeling can provide useful information on the dynamics of industry, employment, and other demographic indicators that would be affected by coastal land loss and also by coastal restoration. Additional tools would be identified during execution of the S&T Plan.

4.3 Demonstration Projects

4.3.1 Purpose and Need

The purpose of demonstration projects is to resolve critical areas of scientific, technical, or engineering uncertainty within the LCA Program while providing meaningful restoration benefits whenever possible. Additionally, demonstration projects would serve to improve the planning, design, and implementation of full-scale restoration projects. Although the scale at which demonstration projects would be implemented may be small relative to the scale at which the technology may ultimately be applied, information gained from demonstration projects could have direct applicability at the intended scale of action.

Demonstration projects should be based on sound scientific and technological theory and practice in order to test the uncertainty in a controlled manner. This strategy would serve to meet the goal of providing information that reduces scientific and engineering uncertainties. However, recognizing that there may be value in pursuing demonstrations of technology or technique combinations, which are new to restoration in Louisiana, there must be flexibility within the Science and Technology Program to pursue demonstrations, which are more experimental in nature when suitable for the advancement of the LCA Program.

The information that demonstration projects would provide is critical to advancement of the restoration program in the near-term. Both full-scale restoration opportunities and large-scale studies may depend upon results from demonstration projects to advance their planning and analysis of alternatives. In order to be responsive to program needs, demonstration projects must also have the ability to be implemented within 1-3 years and provide meaningful results in a relatively short time frame.

4.3.2 Critical Areas of Uncertainty, Defined

Uncertainties may be related to the science, modeling, socio-economic impacts, implementation, technical methodology, resource constraints, cost, or effectiveness of restoration measures. Uncertainties may also be related to development and refinement of forecasting tools. An uncertainty is considered critical if its resolution is vital to advancing the planning and implementation of the LCA Plan in the near-term.

4.3.3 Approach for Demonstration Project Selection and Development

The role of the Science and Technology Program is to identify and prioritize critical areas of uncertainty, to formulate demonstration projects which address those uncertainties, to ensure focused data collection aimed at resolving these areas of uncertainty, and to make recommendations to LCA Program management regarding program and project refinements in light of the reduced uncertainty. Once approval by Program Management to pursue demonstration concepts is given, the Science Office would work with the Program Execution Team to develop necessary documentation to justify implementation.

4.3.4 Identification of Critical Areas of Uncertainty

Critical areas of uncertainty identified by the Program Execution Team, academics, or agency personnel would be proposed to the Science Office Director. Proposed areas of uncertainty should be identified in relation to anticipated program activities. However, the Science and Technology Office would not be constrained to targeting only these needs, and would be open to facilitating the pursuit of new technology, experimentation, and innovative ideas when suitable for the advancement of the Program.

4.3.5 Prioritization of Critical Areas of Uncertainty

Areas of uncertainty would be prioritized based on level of funding and the relative importance of resolution of the uncertainty to advancing the LCA program. The Science Office Director, would be responsible for determining the significance of the uncertainties relative to the advancement of the LCA Program.

4.3.6 Formulation of Demonstration Projects

The Science Office Director would work with the Program Execution Team to determine the most appropriate way to address areas of uncertainty. Timeliness of construction and resolution of the uncertainty must be given great consideration in the formulation process. While resolution of an uncertainty may require that an entirely new project be built, projects currently in the engineering and design phase as well as existing projects may be examined for their suitability in addressing the uncertainty. Additionally, opportunities to resolve multiple uncertainties within one well-designed demonstration project would be sought.

4.3.7 Ensuring Focused Data Collection

The Science Office Director would ensure that data collection and analyses within demonstration projects are aimed at hypothesis testing. Experimentation should be built into demonstration projects as well as existing projects as appropriate; however, collection and analysis of data must be carefully focused to ensure that the targeted uncertainty is adequately addressed. Data collection should be appropriate for resolution of the uncertainty both in the parameters measured as well as in time and spatial scales at which the data are collected. Additionally, proper experimental design must be ensured in order to allow for meaningful data analysis. Prompt reporting of results and recommendations regarding program and project refinements in light of the reduced uncertainty is needed to ensure that findings are useful in advancing the LCA Program in the near-term.

4.3.8 Engineering and Design (E&D) of Demonstration Projects

The Program Execution Team would be responsible for design and implementation of demonstration projects. The S&T Office would be directly involved in the E&D phase of demonstration project implementation to ensure that the project design is appropriate to address the uncertainty. The S&T Office would seek input from experts as needed to ensure that the project is designed and constructed in the most appropriate way.

4.3.9 Potential Demonstration Projects

Many of the potential demonstration projects listed below are primarily responsive to Type 2 uncertainty issues but would clearly address several of the other types of uncertainties. To avoid redundancy, they are only listed here although the other types of uncertainties are discussed within the short description of each demonstration project.

4.3.9.1 Use of dredged material to restore coastal marshes using thin layer disposal techniques

There is the potential to distribute dredged material within interspersed marsh areas to increase elevation to a level suitable for vegetation to spread into currently open water areas. However, the depth and impacts on existing vegetation must be determined and techniques for proper dispersion to maximize plant growth and minimize suffocation of vegetation must be developed. Uncertainty about sources of sediments and appropriate particle size for enhancing productivity and maintenance of the marsh must be investigated. Therefore, it would be necessary to test different methods for thin placement including spray dredge and unconfined/semi-confined traditional hydraulic techniques. Traditional dredging would need a non-granular borrow source over vegetated platforms. Plant mortality should also be tested with different depths of fill. In addition, impacts related to the acquisition of borrow material and its effect on the local ecosystem must be addressed.

4.3.9.2 Methods and outcomes from sediment delivery via pipeline

This uncertainty could likely be addressed by the same demonstration project as the dredged material issue above. Concerns about the cost effectiveness of using conventional dredging techniques to transport large quantities of sediments long distances from sediment sources must be addressed. Conventional dredging equipment typically requires large pipelines for transport of sediments. However, there are uncertainties about how the material can be effectively transported efficiently over long distances and distributed within marsh habitats. Conventional equipment could result in large piles of sediments being deposited above tidal elevations, disrupting vegetative growth, and causing undesirable lateral water movements within the marsh. Therefore, techniques must be developed to effectively transport large quantities of sediments to the marsh and to carefully redistribute those materials within the marsh to appropriate elevations to promote marsh establishment. Additional tests should also be conducted to determine final grade vs. design grade, dewatering periods, and potential water quality effects of transported materials. Tests should also be conducted to apply a two-tiered approach whereby large pipeline systems are used to convey high volumes of material but smaller dredges could be used to then disperse the material into the marshes. Additionally, uncertainties regarding planting techniques on large scales need to be resolved. This demonstration could be used in combination with thin layer disposal described above to examine uncertainties associated with that technology. When offshore sediments are used, the effects of using highly saline material as they relate to creating a healthy marsh environment should also be considered. In addition, impacts related to the acquisition of borrow material and its effect on the local ecosystem must be addressed.

4.3.9.3 Sources for marsh creation, restoration of maritime forests, and restoration of freshwater cheniers

The effects of using saline mineral soils to support freshwater habitats needs to be examined. Uncertainties regarding the time required for soil to leach out salts and increase organic matter content in order to make the soils suitable for the establishment of freshwater vegetation need to be resolved prior to using this technique on a large scale.

4.3.9.4 Combining techniques of marsh platform creation and freshwater/sediment diversion

Individually, marsh creation and diversion techniques have been utilized successfully along the Louisiana coast. Combined, these two techniques may provide even greater results by creating land quickly while sustaining it in the face of relative sea level change. However, uncertainties need to be resolved prior to utilizing this combination of restoration techniques on a large scale. When creating a marsh platform alone, the area is filled to a height that would settle to marsh elevation after dewatering and compaction have occurred. When combined with a diversion, however, it may be more effective to build the platform to a lower elevation and allow the diversion to build the platform to a more natural elevation for marsh establishment. The best combination of initial platform height and diversion operation that would minimize cost and maximize benefits needs to be determined.

4.3.9.5 Operational strategies for water diversions

There would be opportunities to transport large quantities of river water into coastal marshes but uncertainties exist about the most effective operational strategies to maximize restoration benefits. Several recent studies on the Caernarvon water diversion have indicated the potential to enhance marsh establishment below the diversion by altering the operational strategy. Additional studies are needed to test different operational strategies including pulsing methods and timing of delivery of freshwater, sediments, and nutrients from diversions to optimize long-term sustainability of marsh landscapes. There are also concerns about potential water quality degradation due to high nitrate levels in the river water. Therefore, it would be necessary to determine seasonal dynamics of nitrate levels in water sources and determine the assimilative capacity of different coastal vegetative species and different coastal wetland types.

4.3.9.6 Sediment sources for reestablishment of barrier islands and land bridges

Much has been learned about the most effective and sustainable island geometry design from focused research and restoration projects already completed. However, many issues remain regarding the potential sources of the large quantities of sediment that are required to reestablish coastal barrier islands. Two sources already identified are Ship Shoal and the Lower Mississippi River. Issues related to Ship Shoal, a large sand deposit south of Isle Dernieres, are the quantity of available material and the cost effectiveness of using this source relative to other sources. The sources of sands must be clearly identified and different transport mechanisms tested to determine a cost-effective approach to establishment. Studies are also needed to ascertain the type of sediment (percentage of sand/silt/clay) that may be used for barrier islands and back barrier marsh creation while facilitating vegetation growth and island stability.

4.3.9.7 Remediation of canals for marsh restoration

Canals have been cut throughout coastal marshes and their associated dredged material banks have resulted in fragmentation and accelerated loss of many marshes. There has been considerable uncertainty and debate about the most effective approach to remediation of existing canals. There are also uncertainties about the viability of associated marsh restoration efforts and the timing of restoration. Several different approaches to marsh restoration in existing pipeline canals should be examined and monitored including: 1) backfill with small hydraulic dredge; 2) cross dikes to construct cells and improvements on effluent discharge location; 3) mechanical backfill; 4) gaps in the spoil bank to restore natural hydrology; and 5) test plugs as stand-alone features to reduce erosion within the canal. If backfill is used, impacts related to the acquisition of borrow material and its effect on the local ecosystem should also be addressed.

4.3.9.8 Erosion protection structures

Erosion along open bays and channels has lead to wetland losses across the coast. Different approaches to impede future erosion must be examined and effectiveness determined. Methods of construction and prediction of constructed structure sustainability should also be determined. Settlement of various erosion protection/foreshore protection features must also be determined. Efforts would be necessary to construct and monitor a variety of erosion protection/foreshore protection features in a variety of foundation conditions. Improved designs and more accurate project cost projections would also benefit all future related work.

5.0 LCA SCIENCE AND TECHNOLOGY AGENDA

5.1 Objectives

The objectives of this section are to discuss the approach to establish the S&T Office, how the S&T Office would establish priorities for identification of science needs, determine how those needs would be implemented, and identify some investigations that may be initiated during the first three years of Plan execution. Scientific investigations executed through the S&T Office must address specific project execution needs using the best available science and technology. Program Management and the Program Execution Teams would identify priority project needs and the S&T Office would identify necessary science investigations and recommend those studies to Program Management to address those needs.

5.2 General Strategy for Plan Development

Establishing a strategy to systematically and effectively reduce uncertainty to a level where restoration projections can proceed with a reasonable probability of success is the primary goal of the S&T Plan. The general strategy to develop an action plan is comprised of three sub-strategies: (1) enhance program focus by systematically reducing scientific uncertainties, (2) increase efficient use of resources by prioritizing available resources, and (3) establish a program structure to enhance integration of science investigations that reduce uncertainties with the most efficient use of resources.

Each Sub-strategy is discussed below followed by the general form of a plan outlining science steps for the first three years of the S&T Plan. The general strategy would be updated on an "as needed" basis as part of active Adaptive Environmental Assessment and Management. The general strategy would be updated during the first year of program implementation when the Director is identified. Moves to focus the S&T Program and would be updated less often in subsequent years. Specific steps in the three-year action plan would be reviewed and possibly modified when the program is initiated and updated on an annual basis thereafter.

5.2.1 <u>Sub-Strategy to Ensure Program Focus</u>

LCA restoration would be implemented by construction and operation of specific projects that would enhance wetland restoration efforts. A variety of project alternatives are available, each with a different blend of cost, restoration benefit, and impact. Effective project selection must balance these project attributes. However, the clear differentiation between alternative projects, necessary for project selection, is clouded by uncertainties in restoration benefit and impact. The inadequate forecasting of ecosystem response causes this uncertainty. These uncertainties may result from either lack of scientific understanding or imprecise forecasting tools. Moreover, uncertainty is not uniform across all possible projects. Certain categories or sizes of restoration projects may be implemented with relatively little risk of failure whereas other projects categories may be associated with substantial scientific and technological uncertainty. This latter category of project should not be constructed until critical (i.e., project threatening) uncertainties are reduced to acceptable levels.

5.2.2 Sub-Strategy for Effective Use of Resources

Seven general sources of knowledge relevant to the LCA Plan that may be used to reduce uncertainty and thereby guide restoration planning. These knowledge sources can be ranked by increasing cost as:

1) Existing literature and information from other large, coastal restoration projects (e.g., the Everglades),
2) Available but uncollated and unsynthesized data collected under existing programs that can be acquired and analyzed in ways that support S&T Program goals,
3) Professional experience in a community of practice, particularly engineering, may address certain knowledge needs,
4) Bench-, microcosm-, mesocosm-scale studies,
5) Expansion of existing projects to serve as demonstration projects,
6) Field trials using intermediate-scale demonstrations, and
7) Prototype scale demos.

Approaches one to three are relatively low cost and can be implemented early in the 5-year program cycle if the necessary coordination and IT procedures are established early in the program cycle. Approaches four to seven involve direct experimentation, but at different scales. In approach four, uncertainties are reduced by using relatively controlled experiments to describe small-scale processes. Approaches five through seven all involve relatively large-scale, relatively uncontrolled experiments in which routine monitoring is used to describe system response. Approach five may also be relatively low cost depending upon the level of completeness of the existing demonstration. Approaches six and seven require more time for construction and scientific mobilization and should be delayed until approaches one, two, and three have provided information to help focus approaches four and five. Implementation of approach seven falls outside the three-year plan and should be considered as a long-term project in which knowledge gleaned using approaches one through six must be utilized for project planning for approach seven. Effective utilization of this sub-strategy requires the availability of the following items, all part of the S&T Plan:

8) A comprehensive IT plan to allow data and knowledge to be integrated seamlessly across all seven approaches,
9) A comprehensive monitoring plan that is essential to garner knowledge from approaches four to seven, and
10) An integrative model framework that can be used to archive knowledge in a form that can be used directly to support project design, siting, and operation.

5.2.3 Sub-Strategy for S&T Program Structure and Integration

Previous and anticipated research to support the LCA Plan is characterized by studies from various disciplines that typically work on different subsystems or ecological processes within ecosystems. This sub-strategy would be used to assemble and integrate the tools of different disciplines in order to develop a system of forecasting tools to support LCA restoration. The sub-strategy would provide science and engineering capabilities that allow the action agencies to understand the systemic consequences of restoration projects over broad temporal and spatial scales. The capabilities would include science-based water resources management methodologies, implementation guidance, and computational frameworks and technologies that support decision-making. These capabilities would be built from sound, scientific principles reflecting an improved understanding of interrelationships among key system attributes such as hydrology, hydraulics, geomorphology, chemistry, ecology, and socio-economics. Capabilities would be served through an integrated architecture allowing projects to be considered at multiple-scales during project planning, design, construction, operation and maintenance.

The sub-strategy would have four broad topic areas and a unifying technologies area. The topic areas include 1) Water dynamics (including estuarine and coastal dynamics); 2) sediments, water quality, and geomorphology; 3) ecological response; and 4) socio-economic response. This structure is recommend for three important reasons: 1) tools used for ecosystem management can be typically categorized using this structure, 2) IT frameworks that support interdisciplinary integration require at least this level of discipline-specific program resolution (although additional levels may need to be added), and 3) this structure is consistent with the new CE system-wide R&D program scheduled to start in 2005. This last point is particularly important because the CE system-wide program would develop tools that can be used to restore a number of river and coastal ecosystems. Continuity in the S&T Program structure between LCA and the CE system-wide program would ensure that tools developed by any restoration program of national importance can be easily exported to another. For example the CE system-wide program plans to develop a River Basin Morphology Modeling and Management System and a Coastal Morphology Modeling and Management System. The cost effectiveness of such a strategy is obvious.

5.3 Specific Tasks for S&T Plan Implementation

This portion of the S&T Plan provides a brief description of the tasks necessary for formation of the S&T Office, the process for execution of the S&T Plan, and the schedule of tasks planned during the next few years. Given the uncertainty of funding and sequence of project execution during these first few years, the S&T Plan is fairly general. However, as particular projects are identified for early execution during the near-term, priority studies would be initiated to establish baseline conditions and to, subsequently, to determine how effective each project was at achieving its intended objectives.

Execution of the S&T Plan and identification of specific studies should be accomplished with significant input from scientists within Louisiana as well as those outside of the state. The modeling effort, discussed in detail in Appendix C of this report, has performed a substantial amount of work to develop the initial models for assessment of ecosystem response. That effort clearly identified several data needs and that team should be fully engaged, as the S&T Office becomes functional. Therefore, this section of the report proposes that the following tasks be accomplished in the first years of implementation: (1) establish the S&T Office and hire the Director, (2) establish the Science Coordination Board to coordinate LCA Plan activities with other scientific research programs and identify potential opportunities for leveraging funds, (3) establish the Science Advisory Board, (4) initiate review of existing information prior to data collection, (5) develop an Information Management Architecture to handle the different types of data available and anticipated, (6) work with the Program Execution Team to identify future project schedule projections and identify necessary analytical tools to meet those needs, (7) initiate priority research investigations as time and resources permit, and (8) prepare the Annual Adaptive Management Report. Additional priority research would be identified in subsequent years. The LCA Approach to achieve these tasks is presented below.

5.3.1 Establish the S&T Office

Scientific studies for LCA projects should be initiated and coordinated through the S&T Office. Scientific investigations would be interdisciplinary and inter-institutional and awarded on a competitive basis. Scientists participating in the science effort would be expected to provide results in a form usable by the LCA Program Execution Team and in accordance with Program Execution Team schedules *and* publish results in peer-reviewed scientific journals.

Administrative staff for the S&T Office would include an Administrative Assistant (1 FTE), one person (1 FTE) to handle fiscal resources, and two persons to handle contracting (2 FTEs). The fiscal and contracting persons may be located within the District, but must be dedicated full time to the S&T Office.

5.3.2 Establish the Science Coordination Board

Efforts have already been initiated to inventory research programs by Federal agencies and academia and this effort would be expanded as the S&T Office becomes operational. The Science Coordination Board may have representation from the USACE Center of Expertise for Ecosystem Restoration, the Governor's Applied Coastal Research and Development Program, the Coastal Restoration and Enhancement Through Science and Technology (CREST) Program, Pontchartrain Restoration Program, and other organizations as appropriate.

5.3.3 Establish the Science Advisory Board

The Science Advisory Board would be composed of independent, National Academy of Science level, coastal restoration experts. This Board would be convened at regular intervals on a contract basis to review the Program.

5.3.4 Initiate Review of Existing Information

Abundant, multi-disciplinary data archives exist in both public and private sectors that would be extremely valuable to LCA project planning, design, implementation, and monitoring efforts. Information exists in a wide diversity of formats from historical maps and aerial photography to hydrodynamic data, historical ecological data sets, demographic information and more. Data acquisition of physical, hydrodynamic, and ecological data is ongoing and future data mining of these resources is being planned and implemented. These data sets are important in establishing baseline conditions (essential to measure restoration performance), for developing status and trends in the conditions of natural resources, and gaining greater insights in project planning, implementation, monitoring, and evaluation. Clearly, Louisiana has a rich history of scientific studies within the coastal system. However, it is necessary to assess this information, clearly identify what is known and what is not known, and clearly define gaps in our understanding, so that planning efforts may more fully utilize the human and fiscal resources available to the S&T Office and avoid duplication of the expenditures of these resources.

5.3.5 Develop Information Management Architecture

Information technology is a part of every component of the LCA program. Therefore, the Director's office must be involved in the conduct of information technology activities. The Director's office should not physically do, or necessarily lead, information technology development, but must be intimately involved in the planning, development, and distribution of information technologies.

The first information technology task that must be undertaken for LCA Plan is the development of a technical architecture for all LCA Plan products. The purpose of a technical architecture is to define the standards and procedures that scientists and engineers would use in LCA Plan. Among others, there would be standards for spatial and scientific data, frameworks for working with multi-dimensional models and decision support tools, and web-site/portal products. Early definition of standards in the technical architecture would "bake in" interoperability and reusability into LCA Plan products. The size and complexity of the LCA program must have a detailed technical architecture to be technically and financially successful. A technical architecture for LCA Plan can be completed in the first year.

5.3.6 Identify Future Project Schedules

The Director would work closely with LCA Program Management and the Program Execution Team to sequence scientific investigations. Data would be collected prior to project execution to ensure that appropriate baseline information is available and can be used to make pre-project and post-project comparisons and to effectively analyze project results.

5.3.7 Potential Priority Scientific Investigations

The S&T Office and Program Execution Team would identify potential priority studies and analytical tools necessary to reduce scientific uncertainties and meet project needs. Ongoing investigations on Hydrodynamic and Ecosystem Restoration Modeling and the study on Barrier Island and Shoreline Restoration should be examined and considered for future studies and a study on River Management and Engineering would also be considered. These broad studies would provide valuable information for all near-term, long-term, and demonstration projects. Additional studies would be identified as needed during the first year of execution. A brief description of each of these efforts is presented below.

5.3.7.1 Hydrodynamic and ecosystem restoration modeling

The LCA Comprehensive Ecosystem Restoration Plan would establish a modeling framework to provide analytical tools to address Louisiana coastal problems and opportunities for wetland rehabilitation. The early modeling effort supported the LCA planning process by developing preliminary conceptual ecological models of coastal Louisiana. The initial step of this conceptual model was to define disturbances, sources of ecosystem stress, and development of desired ecosystem response. These assumptions were based on causal linkages between disturbances, ecological effects, and desired ecological endpoints or restoration responses. These responses required an understanding of the present ecosystem state, desired endpoints, and necessary site conditions to obtain specific endpoints. Initial work on this conceptual model accomplished a description of these objectives, targets, and desired endpoints; the results of this effort are described in each of the five modules used to simulate system response in Appendix C (Hydrodynamic and Ecological Models).

Continued development of these conceptual and simulation models to further develop an applied science strategy that would support the monitoring and adaptive management efforts within the LCA ecosystem restoration plan is required. The early modeling effort provided a modeling tool that has been used to evaluate restoration alternatives along with ecological benefits using a combination of modules that predict physical processes, geomorphic features, and ecological succession. This modeling program has documented the assumptions and limitations of such an effort, and provided guidance for the improvement of this procedure to reduce scientific uncertainty in model forecasts of restoration projects.

5.3.7.2 Barrier Island and shoreline restoration program

The emphasis of this ongoing investigation is the assessment of Louisiana's critically eroding Gulf shoreline (barrier islands/mainland), and the communities at risk, the modeling of critical coastal processes, and the identification of sediment resources for the development of engineering and management solutions to coastal restoration. Critical processes driving the erosion of Louisiana's Gulf shoreline are a combination of high rates of subsidence manifested in relative sea level change, repeated storm impacts, a diminishing sediment supply, complex patterns of sediment dispersal, and other poorly understood processes of erosion. The Adaptive Management of CWPPRA's Gulf shoreline restoration projects constructed in the Isles Dernieres, Timbalier Islands, and Holly Beach has provided many lessons learned. These may evolve into guiding principles for LCA near-term, demonstration, and long-term Gulf shoreline restoration projects with further investigations.

The success of the restoration of Louisiana's Gulf shoreline requires knowledge of the framework geology and the available sediment resources (Appendix D). Additional knowledge of the complex erosive processes acting on the Gulf shoreline is essential to restoration project design through ongoing Sand Sediment Resources Team (SSRT) coastal geomorphic and sediment budget change analysis. The formulation of coastal process models of sediment dispersal coupled with geomorphic change are critical to predict and achieve LCA Gulf shoreline restoration targets. Coastal engineering solutions to shoreline erosion would require a greater understanding of the temporal and spatial processes acting along Louisiana's coast.

This work has compiled previous research and identified key strategies and approaches to restore and protect the Gulf shoreline and provide broader protection to wetlands and infrastructure. The framework for a conceptual model initiated in Appendix D has been further developed to include consideration of the mixed deltaic sediment headland erosion mechanisms and mud/sand interface and interaction. The dynamic morphosedimentary model requires additional field measurement to calibrate and define the distinct break in slope observed in the submerged profile that defines the eroding shoreface. The percent sand in the islands and distribution of sand across the profile also need to be determined by field measurement. Once these field assessments are made the model can be applied to each coastal segment to provide a complete longshore and cross-shore, littoral budget for sand and fine sediment (for each coastal segment) using the measured retreat rates of the shoreline. Coastal restoration projects can then be evaluated for initial and long-term sediment needs with comparative analysis of various fill sources and construction templates. Adaptive Management analysis of existing and planned CWPPRA would be an ongoing process in order to continue to provide new insights into the engineering design of restoration templates for near-term, demonstration, and long-term LCA Gulf shoreline projects.

A regional approach to sediment management is vital to the long-term success of the coastal restoration program. Sand resource mapping and projected use scenarios would be prepared in a decision matrix format appropriate for regional plan development and comparison. Dredging equipment and cost evaluations would be made to establish feasibility level information appropriate for this level of planning. Needs for further offshore investigations and mapping would be identified.

The role that coastal structures can play in coastal restoration and protection would be evaluated. The performance of existing breakwater and other structural systems would be detailed. Applications where structures can be used to improve the long-term performance of restored coastlines and islands would be identified. Cost effectiveness would be the key criterion in the evaluation for the recommendation of specific structural applications. The above analysis would enable development and evaluation of:

- A project level preliminary design of all island and headland segments with costs, and
- A suggested first phase test program that would target uncertainties with a monitoring and feedback adaptive management system to improve scientific understanding and design approaches.

5.3.7.3 River management study and engineering program

The main focus of this study would be the generation of a water budget analysis of the Mississippi River. This effort is a critical starting point in the development of long-term restoration plans. Daily discharge data (1935 to present) are available for the Mississippi River at Tarbert Landing. This database gives a sound basis for developing a statistical analysis of flows in the lower Mississippi River. The discharge information must be representative of any ongoing or future operation of the MR&T flood control system and/or make allowance for any contemplated changes. The water budget analysis must take into account riparian users, navigation, and flood control needs. An LCA plan for use of the river's resources must be developed so that restoration efforts can be directed in the most efficient approach. Central to this issue would be the establishment of realistic restoration goals that take into account the various demands that are placed on the river's resources. It cannot be over-emphasized that the use of the Mississippi River as a resource for coastal environmental restoration is complicated by a host of potentially conflicting demands on that resource.

Selecting the proper location and sizing of a diversion structure go hand in hand. The size or capacity of a structure is proportional to the time-based, land-building scales that are established for the receiving area of any proposed diversion. Conceptually, it seems apparent that the ability to build land in a specific receiving area would be proportional to the volume of water placed in the area via a diversion structure and the concentration of sediments contained in that volume of water. However, in practice, a process-based determination of the land building is perhaps one of the most challenging problems that water resource engineers and scientists confront. Many, if not all of the forcing functions that act on a diversion system are stochastic in nature, and when considered from process-based, deterministic approach, defy existing scientific methodologies. The methodology employed in the current effort relies on averaging long-term observations of these forcing functions. For the Mississippi River, average monthly discharge and sediment concentrations were used. A Risk-Based Analysis approach to the problem of river diversions and expected outputs would need to be considered in future work, so that planners can better understand the uncertainties involved.

In general, planned diversions may be grouped into two classes, controlled and uncontrolled. Uncontrolled diversions, as the name implies, allows for diversion of river flow through an open channel that connects the river to the receiving area. The amount of flow to the receiving area is controlled by the hydrologic cycle of the river and the size of the opening in the riverbank as well as other factors discussed below. Controlled diversions imply that some sort of gated control structure is used to regulate the amount of flow passing into the receiving area. Controlled structures can be operated either as run-of-the-river structures (i.e., allowing the river's hydrologic cycle to dictate discharge) or, as pulsing structures where gates are opened and closed to meet specific timing of flow requirements to the receiving area. Engineering calculations and procedures needed to size a proposed structure and delivery channel (when seeking to optimize the delivery system from the standpoint of total cost) result in a thorough understanding of the discharge capacity of a proposed structure. In general, for a given discharge in the Mississippi River, the further up river one goes the greater the potential head becomes, since for the most part the receiving areas are located at or near sea level. The combination of head and discharge constitutes a measure of the power available to force flow and sediment to the target area. Therefore it would seem obvious that upstream structures, at least in theory, can be smaller in size for a specified diversion discharge capacity than ones having the same discharge capacity located some distance downstream. The problem with this reasoning is that many of the target receiving areas are located near the coastal zone and the channels lengths needed to move flow and sediment to the target area become larger, longer and more expensive to construct as distance from the target receiving area increases. So, proximity to the receiving or target area is an important factor in locating a proposed structure. Therefore, proper selection of location and sizing a LCA system of diversion structures is not a trivial matter and proper planning and forethought must be done to take full advantage the Mississippi River as a source of sediment and nutrients.

5.4 Making Adaptive Management Work

The structures and process outlined here for the LCA Science and Technology Program provide the important elements of an adaptive management program. However, really making adaptive management work means that all participants involved in the LCA Restoration Plan acknowledge that implementation is a learning process, and adaptation must occur. Recognizing that structures would develop and change over time, the specific program elements proposed here are designed to promote learning and adaptation from the start – rather than making adaptive management a concept added on to the existing restoration planning. The LCA Restoration Project would provide an opportunity for participants to begin adaptive management in the early stages of program planning.

5.4.1 <u>The Need to Promote Learning in LCA</u>

Conceptual and predictive models represent the current status of understanding the natural system, and as such are important vehicles to capture the learning that is essential during the adaptive management approach. The revision of models represents a learning process and is the feedback that corrects restoration implementation and helps direct future planning efforts. The challenge is to communicate this potentially complex body of information to scientists, planners, managers, stakeholders, and partners to provide for learning. This would be done through the following:

5.4.1.1 Synthesis of monitoring data

Synthesis of monitoring data and analysis is a key link in the AM process. A key role of the S&T Office is to produce periodic synthesis documents for Program Management and the Program Execution Team that both summarize monitoring data and use the data to verify existing models. The monitored data can provide support for, or lead to modification of, the essential ecosystem characteristics of a conceptual model that has been reviewed and accepted by the public and scientific community. Further, modeling synthesis documents can focus future monitoring, or targeted research, on areas of greatest variability or restoration risk.

5.4.1.2 Evaluation of experimental manipulations

The enhanced value of scientifically designed and adequately monitored, large-scale experimental manipulations derives from the inferences that can be drawn from their results. For example, it should be possible after a period of diversion operation at a certain discharge regime to not only know how plant composition and distribution at the receiving area changed, but what the likely results would be if the duration or timing of the operational regime were modified in the future. Clearly there would be limited "learning" returns from the extensive monitoring of projects that are primarily intended to repeat well-known and tested management actions. However, innovative and untested actions should be considered not just as important learning opportunities but perhaps the only learning opportunities that exist, and therefore they should be supported with strong scientific designs and monitoring programs.

5.4.1.3 Report card

One developing form of reporting on system management performance is the environmental report card (Harwell et al., 1999). As all of us are familiar with report cards from our school years, this familiar manner of evaluating performance can be usefully applied to environmental management programs. An environmental report card presents summary status information on ecosystem endpoints, and it communicates progress of management in improving ecosystem health. Being a communication tool, the report card should be easily understood by a range of audiences. It should communicate the status of the system in terms of endpoints, and reflect trends over time to judge progress. Finally, the method for assigning ratings or grades should be easily understood and clearly based on endpoint definitions and measures. The best formats for progress reporting should make it easy for users to understand the desired endpoint value, current status relative to the endpoint target, and trend through time in status change.

There is no standard format for an environmental report card. However, some common elements of environmental performance reporting are seen in the report cards on ecosystem management by state and federal agencies in the Everglades, Chesapeake Bay, and San Francisco Bay. Performance reporting on the Everglades (McLean and Ogden 2000) and Chesapeake Bay use one simple bar chart or line graph for each endpoint showing annual measurement values by year. These graphs also clearly show the desired endpoint value for readers to readily judge status and trend.

5.4.1.4 Science symposia

The scale and complexity of the Louisiana coastal ecosystem and the expected variety of restoration activities that will be ongoing under LCA mean that few scientists, if any, would be fully aware of the status of scientific understanding. To promote dissemination of current findings, discussion of new ideas, and cross-disciplinary interaction, the S&T Plan would regularly hold a Science Symposium providing a common forum for presentation of results and progress in restoration science. This would be modeled after the already established and successful CALFED Science Conference and the Greater Everglades Ecosystem Restoration Conference – each of which is held biennially. These venues provide excellent opportunities for stakeholders, as well as scientists, to stay abreast of current scientific developments pertinent to ongoing ecosystem restoration efforts.

5.4.1.5 The annual science report and plan

In order to clearly identify the changing scientific needs of LCA implementation, the S&T Plan would annually prepare a 'Science Report' summarizing progress, identifying challenges and unmet needs, and providing some accountability for the funds expended on S&T Plan activities. This would be prepared by the SCB and would encompass LCA supporting science efforts, funded by agencies of other LCA-independent entities, as well as activities specifically funded by LCA. Emerging from the Science Report would be an accompanying annual Science and Technology Plan, which would articulate the activities of the program in the next year as part of a multi-year vision for LCA science needs.

5.4.2 Adaptation - Closing the Adaptive Management Loop

Learning and adaptation are the elements of an adaptive management process that close the feedback loop and begin the iterative process over again. In this phase of the process, information, in the form of monitored data, the results of demonstration projects and other focused studies, and predictive models are combined to yield either confirmations of existing beliefs, or new descriptions of system status and explanations of the factors that control the system. Over multiple iterations of the adaptive process, a new understanding of how the system operates may even result in the reformulation of goals and objectives.

The concept of adaptation is relatively simple. Disciplined adaptation, however, within a program that addresses the desires of many different stakeholders, is a difficult process to implement and control.

In addition to the many other problems associated with implementing adaptive management discussed in the LCA Report and in this appendix, there is also the question of "When to adapt?." While the acquisition of some information can be planned (e.g., from a controlled experiment or a monitoring program), other information arrives unexpectedly. The ability to acquire knowledge about the response of the delta-building process to periodic, large-scale disturbances cannot be predicted.

Adaptive management of any large ecosystem requires both the ability to change on a regular, predictable schedule, and also, if necessary, in rapid response to unpredicted events. Given what we know about year-to-year variability of riverine and meteorological drivers, it seems realistic to consider establishing a regular system status review on a time schedule of 5 years. However, a rapid response decision-making mechanism should be considered as a vital element of a future adaptive management process.

Finally, LCA stakeholders and partners, as they continue to refine a more integrated goal-setting process, must consider the importance of well-thought-out, long-term goals, and the need to take a conservative approach to changing those goals from one adaptive interval to another. The restoration of desirable conditions for many of the ecosystem elements of the Louisiana coastal ecosystem is likely to require decades rather than years. Success would require unwavering commitment as well as vision.

6.0 LITERATURE CITED

Barras, J., S. Beville, D. Britsch, S. Hartley, S. Hawes, J. Johnston, P. Kemp, Q. Kinler, A. Martucci, J. Porthouse, D. Reed, K. Roy, S. Sapkota, and J. Suhayda. 2003. Historical and projected coastal Louisiana land changes: 1978-2050: USGS Open File Report 03-334, 39 p.

Barras, J.A., P.E. Bourgeois, and L.R. Handley 1994. Land loss in coastal Louisiana 1956-90. National Biological Survey, National Wetlands Research Center Open File Report 94-01. 4 p. 10 color plates.

Boesch, D. F., M. N. Josselyn, A. J Mehta,., J. T. Morris, W. K. Nuttle, C. A. Simenstad, and D. J. P Swift. 1994. Scientific Assessment of Coastal Wetland Loss, Restoration and Management in Louisiana. Journal of Coastal Research. Special Issue No. 20.

Coalition to Restore Coastal Louisiana (CRCL). 1989. Coastal Louisiana, Here Today and Gone Tomorrow: A Citizen's Program for Saving the Mississippi River Delta Region to Protect Its Heritage, Economy and Environment. Coalition to Restore Coastal Louisiana, Baton Rouge, LA.

Dunbar, J.B., M. Blaes, S. Dueitt, and K. Stroud. 1994. Geological investigation of the Mississippi River deltaic plain, Report 2 of a Series. Technical Report GL-84-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Dunbar, J.B., M. Blaes, S. Dueitt, and J. May. 1995. Geological investigation of the Mississippi River deltaic plain, Report 3 of a Series. Technical Report GL-84-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Dunbar, J.B., L.D Britsch,, and E.B. Kemp. 1992. Land loss rates: Louisiana Coastal Plain. Technical Report GL-92-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 28p.

Fisk, H. N. 1944. Geological Investigation of the Alluvial Valley of the Lower Mississippi River, US Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS.

Fisk, H.N. 1952. Geological Investigation of the Atchafalaya Basin and Problems of Mississippi River Diversion, Vol. I and II, US Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS.

Frazier, D. E. 1967. Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology. Transactions Gulf Coast Association Geological Society, Vol. XVII, pp 287-315.

Harwell, M. A., V. Myers, T. Young, A. Bartuska, N. Gassman, J. H. Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card. Bioscience 49(7):543-556.

Herke, W.H. 1993. Testimony before the Panel on Scientific Principles of Coastal Wetland Loss, Restoration and Creation in Louisiana, Baton Rouge, Louisiana, October 27, 1993.

Holling,C.S.and L.H. Gunderson. 2002. Resilience and Adaptive Cycles. In: Panarchy: Understanding Transformations in Human and Natural Systems. Gunderson, L.H. and C.S. Holling (Eds.). Island Press, Washington, D.C.

Keithly, W. 1991. Louisiana Seafood Industry Study: A Summary. New Orleans, Louisiana: Louisiana Seafood Promotions and Marketing Board, 32 pp.

Kolb, C. R., and J. R Van Lopik. . 1958. “Geology of the Mississippi River Deltaic Plain, Southeastern Louisiana.” Technical Report 3-483, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

May, J. R., 1984. Geological investigation of the Mississippi River deltaic plain: Technical Report GL-13-84, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

McKee, K.L. and I.A. Mendelssohn. 1989. Response of a freshwater marsh plant community to increased salinity and increased water level. Aquatic Botany 34, 301-316.

Michot, T.C. 1993. Testimony before the Panel on Scientific Principles of Coastal Wetland Loss, Restoration and Creation in Louisiana, Baton Rouge, Louisiana, October 27, 1993.

Minnello, T.J. and R.J. Zimmerman. 1991. The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp. In: DeLoach, P., W.J. Dougherty, and M.A. Davidson. (eds.), Frontiers in Shrimp Research Amsterdam: Elsevier Science Publishers, pp 1-16.

Montague, C.L., A.V. Zale, and H.F. Percival. 1987. Ecological effects of coastal marsh impoundments: A Review. Environmental Management 11, 743-756.

Morris, J.T., 1991. Effects of nitrogen loading on wetland ecosystems with particular reference to atmospheric deposition. Annual Review of Ecology and Systematics 22, 257-279.

Morris, J.T., B. Kjerfve, and J.M. Dean. 1990. Dependence of estuarine productivity on anomalies in mean sea level. Limnology and Oceanography 35, 926-930.

Penland, S., K.E. Ramsey, R.A. McBride, J.T. Mestayer, and K.A. Westphal. 1988 Relative sea-level rise and delta-plain development in the Terrebonne Parish region: Louisiana Geological Survey, Coastal Geology Technical Report No. 4, 121 p.

Reed, D.J. 1989. Patterns of sediment deposition in subsiding coastal salt marshes, Terrebonne Bay, Louisiana. The role of winter storms. Estuaries 12, 222-227.

Shlemon, R.J. 1972. Development of the Atchafalaya Delta, Louisiana, Report 13, Center for Wetland Resources, Louisiana State University, Baton Rouge, LA.

Smith, L.M., J.B. Dunbar, and L.D. Britsch. 1986. Geomorphological Investigation of the Atchafalaya Basin, Area West, Atchafalaya Delta, and Terrebonne Marsh, Vol 1 and 2, Technical Report GL-86-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Templet, P.H. and K.J. Meyer-Arendt. 1988. Louisiana wetland loss: Regional water management approach to the problem. Environmental Management 12, 181-192.

U.S. Army Corps of Engineers (USACE). 1951. The Atchafalaya River Study, Vols. I, II, and III, Mississippi River Commission, Vicksburg, MS.

U.S. Geological Survey (USGS). 2003. USGS Director's Workshop on Science for Natural Systems Restoration.

Wallace, W.E. 1966. "Fault and salt map of South Louisiana," Gulf Coast Association of Geological Societies, Vol. 16.

Wells, J.T. and H.H. Roberts . 1984. Evolution and Morphology of Sedimentary Environments, Atchafalaya Delta, Louisiana, Gulf Coast Association Geological Society Transactions, Vol. XXXI, pp 399-408.